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Analysis of the Challenges and Opportunities of Hydrokinetic Turbine Development Affecting the US Army Corps of Engineers

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BACKGROUND: National energy policy supports increased development of green (renewable) energy to lessen dependence on petroleum-based fuels and reduce their attendant environmental impacts. One family of renewable energy technologies experiencing increased national interest is hydrokinetic turbines. Hydrokinetic turbines include systems that convert waves, tides, and river flow (without impoundment) into electric energy. River hydrokinetic turbines (hereafter referred to as kinetic energy turbines (KETs)) were the focal point of a recent workshop, although hydrokinetic turbines in estuarine or coastal settings may also impact US Army Corps of Engineers (USACE) missions.

This document summarizes a two-day interagency workshop that was convened at the US Army Engineer Research and Development Center (ERDC) on 29 February 2012. The workshop was attended by representatives of the US Geological Survey; Fish and Wildlife Service; National Park Service; Department of Energy (DoE: Oak Ridge, Pacific Northwest, and Sandia National Laboratories); US Coast Guard; USACE Headquarters; USACE New Orleans District; Mississippi State University; and ERDC's Environmental Laboratory (EL) and Coastal and Hydraulics Laboratory (CHL). A complete list of attendees can be found in Appendix A. Recorders at the workshop summarized information from both the presentations and ensuing discussions. This Technical Note succinctly synthesizes information developed during the workshop, capturing major discussion points and conclusions. This information was analyzed to identify challenges such as internal communication shortcomings, external coordination requirements, and critical technology gaps. By addressing these challenges, USACE is poised to effectively execute its Federal responsibilities in support of the national green energy policy. Additionally, a consistent roadmap of USACE expectations and requirements that can be used by developers when they enter the "one door to the Corps" will expedite the national goal of green energy.

Purpose and objectives. The purpose of the workshop was to describe institutional and technology issues facing USACE as the Nation proceeds with development of KETs. The workshop was structured to meet the following specific objectives:

1) Summarize ongoing research and development at Federal laboratories and elsewhere that would be of interest to the attendees. Specifically, describe hydrokinetic energy development status and assess the likelihood of implementation in the short term (1-2 years) and long term (more than 2 years).
2) Identify potential mission actions (Regulatory, permitting, and coordination) with which USACE should engage. A critical question that the workshop attempted to address was, "Is

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adequate information being developed now to address anticipated permitting data requirements?"

3) List and briefly describe critical research and development needs to address unresolved navigation, flood risk management, and environmental issues.

Workshop organization. The KET workshop was organized into two sessions to meet the objectives listed above. Day 1 was an open session in which speakers from different agencies presented information on issues or emerging technologies specifically to address Objective 1 (Technology Status and Needs Assessment). Day 2 was restricted to USACE attendees and featured perspectives of different mission areas addressing Objective 2 (Mission Status and Needs Assessment). Discussion of present, emerging, and anticipated issues and needs of specific interest to USACE was encouraged. Findings from the Day 1 presentations and the Day 2 discussions were integrated to address Objective 3.

WORKSHOP SUMMARY

Day 1–Technology Status and Needs Assessment

Presentation summary. After a brief introduction by the conveners, Day 1 of the workshop began with 10-minute presentations by USACE business line managers for navigation (James Walker), hydropower (Kamau Sadiki), and Regulatory (Amy Klein). These presentations were critical because the corporate perspectives of each speaker structured the second day of deliberations.

For clarity and brevity, the rest of the presentations are not described in the sequence in which they were given, but rather in the order of how they contributed to the overall narrative. The actual sequence of presenters and their titles can be seen in Appendix B (Workshop Agenda). The following summary is included to describe the general flavor of the presentations. Detailed notes taken during the presentations can be reviewed in Appendix C and copies of the slides can be found in Appendix D. Mr. Stephen Bowler of the Federal Energy Regulatory Commission (FERC) summarized the mission responsibilities of his agency, the FERC license process, and the agency interfaces (with emphasis on USACE interfaces) typically required for the hydropower licensing process. Department of Energy (DoE) representatives (Drs. Neary, Jepsen, and Grippo, and Mr. Weiland) from four national laboratories (Oak Ridge, Sandia, Argon, and Northwest Pacific, respectively) gave coordinated presentations providing a comprehensive overview of how the DoE hydrokinetic program was distributed and implemented within their agencies. They also summarized the status of hydrokinetic turbine development of many types (not just KETs), the different types of applications, the status of tools that could be used to describe or assess the operation and performance of KETs, and the types of environmental impacts that could be anticipated. Dr. Alex Haro of the USGS gave a presentation on studies, both ongoing and anticipated, describing likely physical effects of KETs on different species and life stages of fishes. Dr. William (Bill) McAnally of Mississippi State University summarized fundamental effects of kinetic energy extraction on the hydraulic regime of an open river. He then connected a suite of issues of importance to USACE to these fundamental effects. Mr. Randy Thoreson of the NPS presented his agency's perspective on KETs progressing from identification of impacts to their likely direct and indirect effects on recreation and other social dimensions. George Detweiler of the US Coast Guard summarized his agency's roles and responsibilities in KET development. Paul

Hartfield summarized studies conducted by his agency and colleagues at Mississippi State University describing how microhabitat associations of the endangered pallid sturgeon could be affected by KETs. Will Veatch and Brenda Archer of the New Orleans District jointly presented a summary of their agency's experience dealing with the complex array of technical, coordination, and permitting issues associated with KETs. Their presentation was particularly valuable because the New Orleans District is one of the first USACE districts dealing with what may become a major increase in KET inquiries.

Day 1 summary. A number of important conclusions about KET environmental impacts and the tools to assess them were developed during the workshop.

Conclusions about environmental impacts associated with KETs can be separated into two categories: geophysical and biochemical effects versus the effects on higher trophic levels. Most geophysical effects and some biochemical effects can be inferred from Figure 1 (from the presentation by Dr. Bill McAnally). This figure compares average cross-section hydraulic conditions (depth and velocity) at cross sections both with and without a 10% kinetic energy extraction base-lined to the hydraulic control structure located at 0 m. A change in hydraulic characteristics of the magnitude shown in Figure 1 produces a cascade of effects. First, the reduction in energy slope will increase water surface elevations as well as alter the erosion and deposition regime in the wake of each KET. In the longer term, shifts in the erosion and deposition regime (and debris loading) to a new equilibrium in an array has the potential to affect channel geomorphology and flow pattern. These alterations in the geophysical environment affect water quality patterns in the short term by altering residence times of constituents. In the long term, the alterations affect those parts of water quality patterns that are coupled to sediment dynamics. The effects of KETs on geophysical variables and water quality dynamics generally described above (plus other effects that are more direct and therefore easier to understand) can be connected to higher trophic levels in a marine environment using conceptual models, either for a single KET (Figure 2) or an array of KETs (Figure 3).

The precise magnitude and extent of potential impacts will be determined by flow, season, number of units and their distribution, local hydrology and geomorphology, degree of existing river infrastructure (e.g., levees, dams, and harbors) and other site-specific factors. More precise forecasts and assessments of impacts are difficult to quantify without additional detailed information. However, the potential impact of an extraction of 10% of the kinetic energy of river flow can be analytically shown to have a substantial impact on a number of important flow variables (Figure 2) that, in turn, affect other resource categories. Figures 2 and 3 depict effects of KETs in a marine environment; however, conceptually similar effects can be expected in estuarine and river environments.

Evaluations of the accuracy of tools to forecast and assess the environmental effects of KETs varied by discipline. Physics-based models (both numerical and physical modeling tools) are relatively mature in their development, so that relatively robust statements can be made about impacts on the geophysical environment, although a few unresolved issues remain. For example, it is difficult to include the small-scale hydraulic effects of individual turbine blades within larger-scale modeling efforts that must simulate conditions within a spatial domain many kilometers in length.

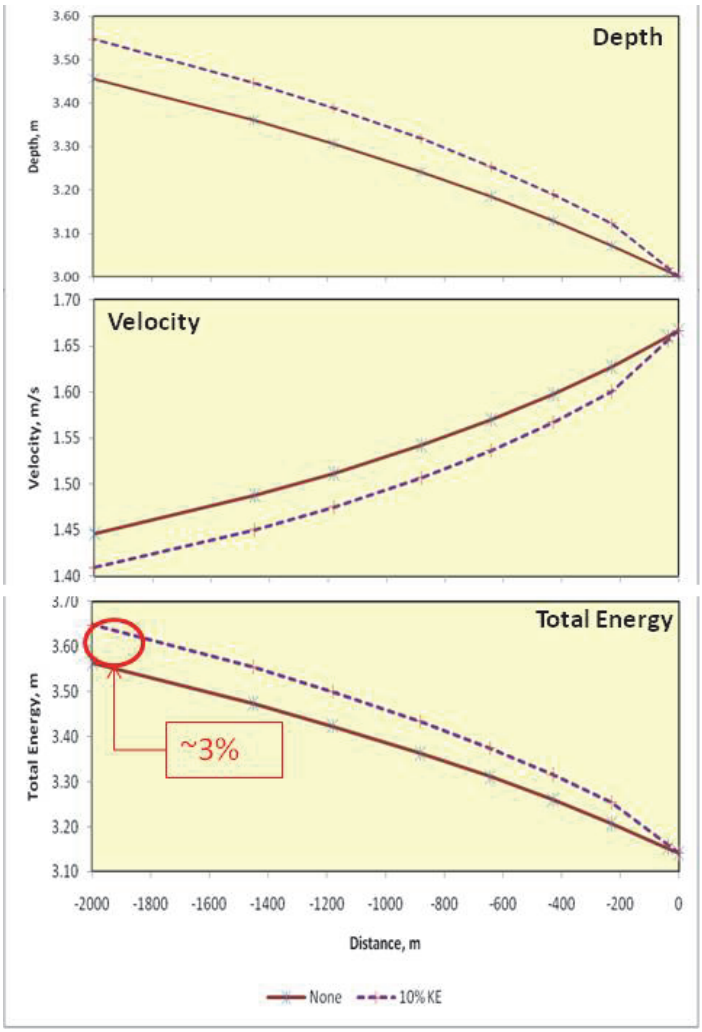


Figure 1. Upstream effects from a hypothetical hydraulic control structure at 0 m comparing with and without KETs. Note substantial effects on energy slope, average velocity, and flow depth for a uniform channel where Q=10,000 m-3 sec-1, roughness (n)=0.025, bottom slope = 0.0001, KE coefficient = 1, tailwater depth = 3 m, and kinetic energy extraction = 10%. Note the substantial upstream effects of kinetic energy extraction on river depth and velocity, which affects stage-discharge relationships and conveyance of sediments and nutrients.

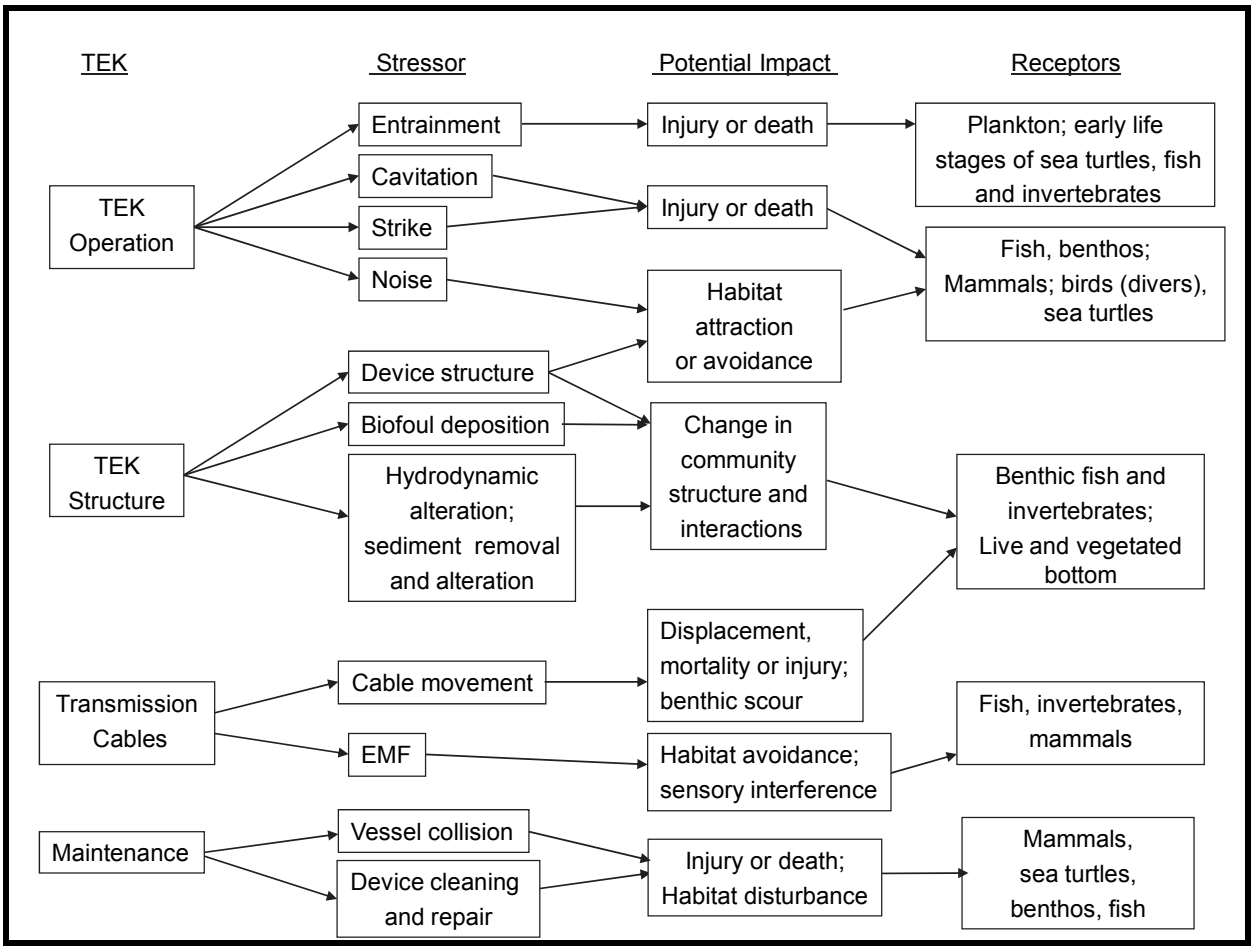


Figure 2. Conceptual model of expected impacts of a single KET deployment in a marine environment. Conceptually similar effects can be anticipated in estuarine or riverine environments. The conceptual model does not include construction impacts (taken from a presentation by Dr. Mark Grippo).

The relative maturity of physics-based forecasting tools mean that a number of alternative approaches may be available for each application. Unfortunately, experience has shown that applicants are typically supported by their own cadre of modeling professionals, each using different, often proprietary, models. To avoid confusion and expedite the licensing process, there is value in establishing "reference models" to address specific aspects of the geophysical effects of KETs. Each reference model will include documentation of state variables, appropriate boundary conditions, and relevant time and space scales to adequately address specific geophysical effects. These public-domain models can be used to develop baseline costs of energy and to identify cost reduction pathways. They will be based on generic KET designs commonly used in high kinetic energy environments and based on real data. With this approach, both applicant and regulator can be assured that best science is used when an applicant chooses a model with attributes similar to the reference model. Geophysical uncertainties still exist that limit the forecast accuracy of physics-based models. For example, the degree to which the structures (posts, reinforcements, and cabling systems) used to deploy KETs are subject to debris loading is unknown. These unknown factors create uncertainties about the effects of debris loads on hydraulic characteristics and fluvial

geomorphology response. FERC encourages relatively small-scale pilot studies to address local physical impacts of individual KETs. At the larger scale, monitoring of effects based on the tenets of adaptive management is required to address population, community, and ecosystem-level impacts.

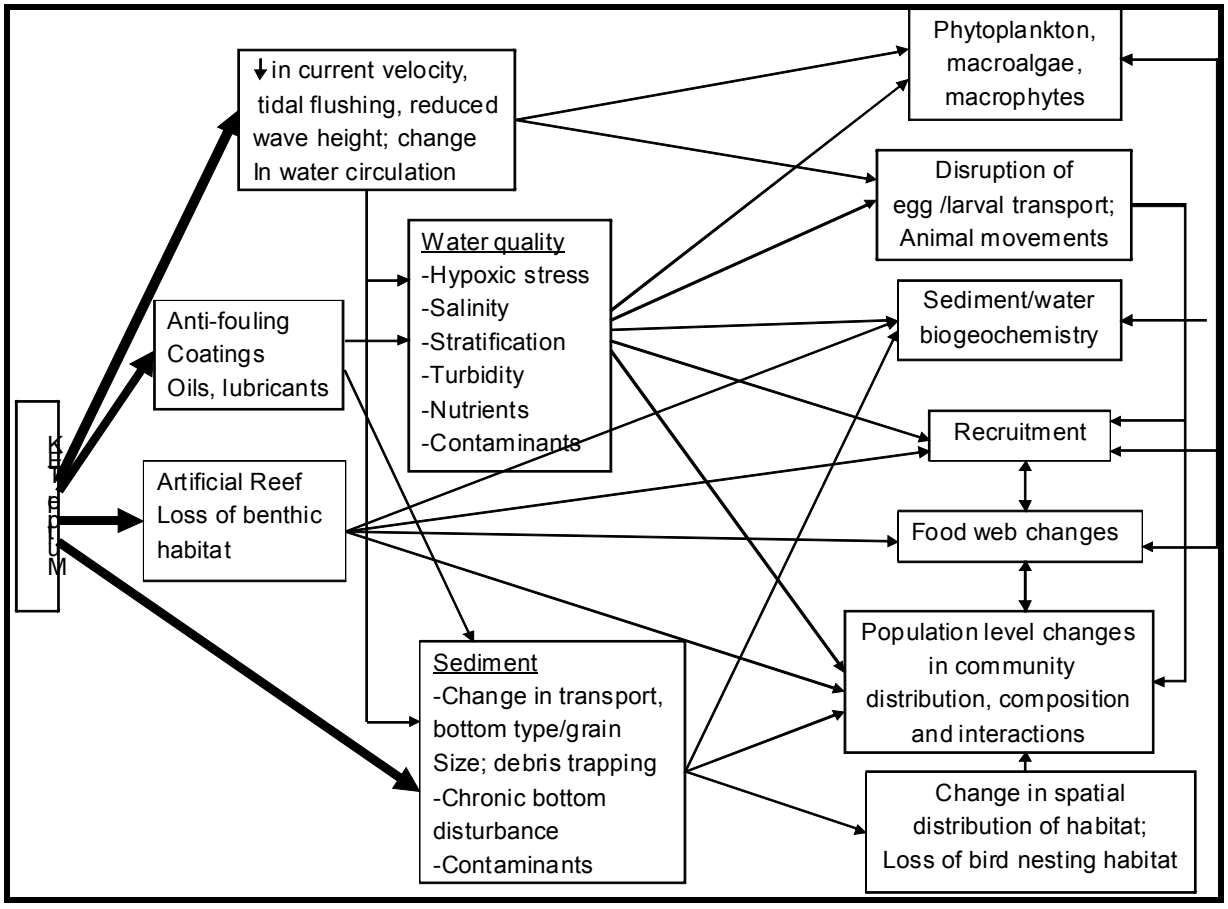


Figure 3. Conceptual model of expected impacts of an array of KETs deployed in a marine environment. Conceptually similar effects can be anticipated in estuarine or riverine environments. The conceptual model does not include construction impacts (taken from a presentation by Dr. Mark Grippo).

Ecological response models are less mature than physics-based models, particularly for effects that are longer-term or far-field in nature. A number of concerns were identified by Dr. Paul Hartman of the US Fish and Wildlife Service (USFWS) on impacts of living resources that should be addressed by field studies. There are also a large number of water quality, population, and community models that could be used to forecast and assess impacts of KETs at various time and space scales. It is beyond the purview of this technical note to discuss them in detail. However, several presenters at the workshop expressed interest and/or presented coordination plans for the use of the Numerical Fish Surrogate (NFS) family of models. These models were developed at ERDC to address direct impacts (e.g., blade strike) and indirect effects (e.g., alteration in movement behavior) on various fish species. There appeared to be a consensus that the NFS type of models should be developed to more efficiently evaluate some aspects of the environmental impacts of KETs. This family of high-fidelity models can be used in conjunction with monitoring

data of different scales and high fidelity Computational Fluid Dynamics (CFD) modeling. This combination provides the fine-scale resolution necessary to address many of the more difficult ecological questions associated with KET development.

USACE institutional involvement in KET development is clearest from a Regulatory standpoint (see summary in Text Box A). KET developers require both Section 10 (Rivers and Harbors Act 33 U.S.C. 403) and Section 404 (Clean Water Act) permits and both USACE permitting actions are typically coordinated with FERC as the lead agency. In addition, USACE internal coordinating activities are conducted from the perspective of the KET EIS to ensure that issues associated with major USACE mission responsibilities are addressed.

TEXT BOX A: Summary of Existing USACE Permit Process

Required USACE Permits:

- Section 10 (Rivers & Harbors Act of 1899)–structures / work affecting course, location, or condition of Navigable Waters
- Section 404 (Clean Water Act) - discharges of dredged or fill material into waters of the United States

USACE (MVN) Process (FERC as lead Agency)

- Pre-application Consultation (optional)
- Permit Application Submission
- Review of Permit App (incl. Public Interest Review)
- Permit Decision

Internal USACE Coordination

- Navigation and Hydropower

Public Interest Review of KET EIS

- Water Quality
- Wetlands
- Fish and Wildlife
- Navigation
- Floodplain Management (Sedimentation, Flowline, Channel Stability)

One of the most important findings from the workshop was the sheer number of proposed KETs for the Lower Mississippi River. Fields of KETs numbering in the tens of thousands have been proposed. Each KET will likely have a relatively minor effect because of its small size (1- to 3-m turbine blade-tip diameter). However, fields of KETs that extract up to 10% of the kinetic energy of the river will likely have a substantial impact on a number of physical processes (Figure 1) and the biogeochemical cycles, living resources, and human uses coupled to these physical processes. A generalized cascade of biological to ecosystem-level impacts and agency mission considerations is shown in Figure 4.

Figure 4 also demonstrates that KETs have the potential to affect USACE mission areas beyond the Regulatory mission. KET development has the potential to directly affect major USACE mission areas such as navigation, flood control, and ecosystem restoration. The reduction in average channel velocity may increase sedimentation within a navigation channel, which will require an increase in channel maintenance activities. Increased water depth will affect the stage discharge relationship that is used to calculate flood risk and could affect levee heights needed to protect against floods of a specific recurrence interval. Alteration of the physical environment by arrays of KETs will also likely affect both upstream and downstream stage-discharge relationships, which are often the basis of USACE project EISs. Therefore, KETs can affect existing USACE projects in ways not addressed in the original USACE project NEPA documentation and, therefore, affect USACE project benefits in unexpected ways. The general conclusion from the presentations by Will Veatch and Brenda Archer (both of MVN) was that many concerns remain to be addressed about the effects of KETs.

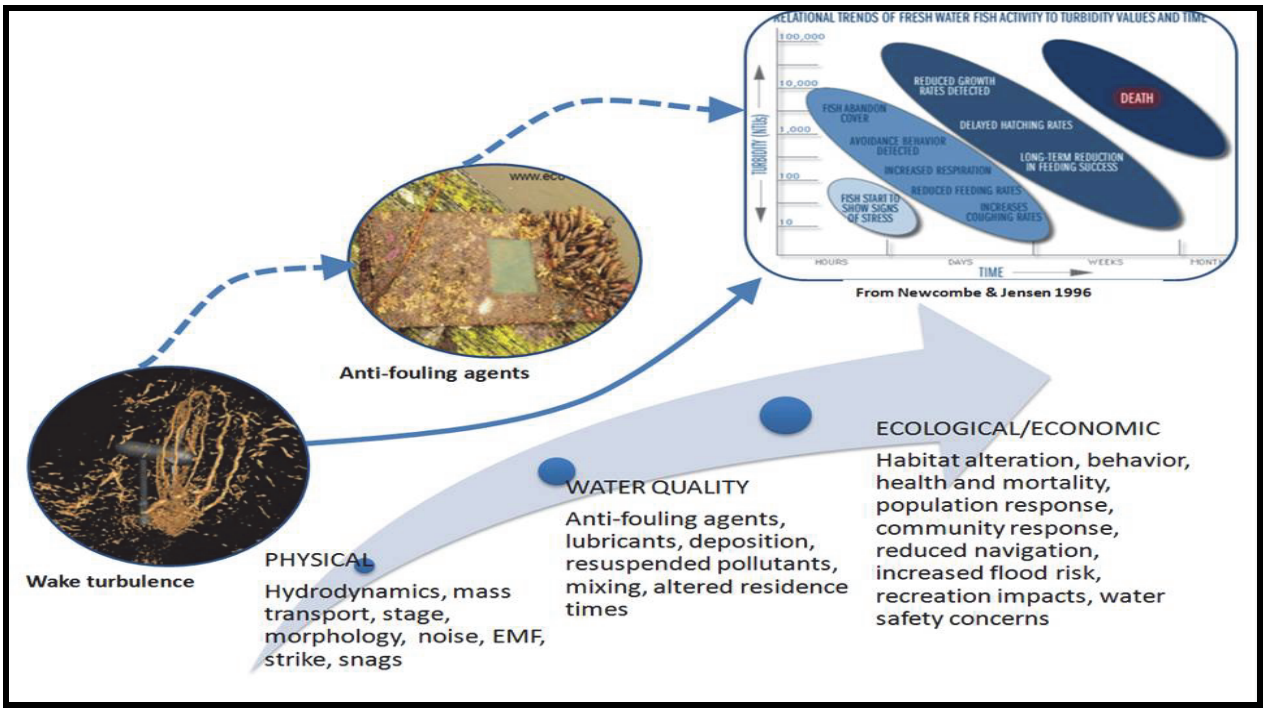


Figure 4. Generalized **c**ascade of coupled physical and chemical processes, living resources, and human uses affected by large fields of KETs (modified from Vincent Neary workshop presentation).

The first day presentations confirmed the large amount of uncertainty surrounding direct effects of KETs (e.g., fish entrainment and mortality, installation and maintenance, construction of shoreline facilities on maintained river levees, modification of levees for power lines and utilities access) and indirect effects (e.g., wake sedimentation and debris loading of turbine support structures (posts, struts, and cables) induced by reduced water velocity). The major finding from the Day 1 summary is that the number of USACE mission areas affected by KET and their interactions deserve further evaluation, discussion, and synthesis.

Day 2- Mission Status and Needs Assessment

Day 2 of the workshop began with a summary of the previous day's most significant events followed by a short session to identify technology needs to adequately forecast impacts of KET development. An open discussion ensued in which a variety of topics were introduced and explored. The discussion was far-ranging, reinforcing the perception that issues associated with KET development are complex and affect many agencies and a number of critical USACE mission areas. The following three related topics were discussed and are briefly described later in this techical note:

- Department of the Army permit program (Regulatory)
- Process by which the Corps addresses its responsibilities under Section 408 (Civil Works)
- Protection of navigation, flood control, and other Federal investments (for which USACE is responsible) from the negative impacts of hydrokinetic projects.

Relationships among the three topics are symbolically represented in Figure 5. Note that FERC is the lead Federal agency for Hydropower License application and that USACE supports FERC. The relationship between FERC and USACE (based primarily on procedures developed and used within MVD) is summarized briefly below to give context to the recommendations at the end of this technical note. For brevity, the descriptions below do not include the considerable internal and external coordination that characterizes the USACE response to each license application. More specific responsibilities of USACE in support of FERC KET license decisions are described in detail in "Memorandum of Understanding between United States Army Corps of Engineers and the Federal Energy Regulatory Commission on Non-Federal Hydropower Projects" dated 30 March 2011 (*http://www.usace.army.mil/Portals/2/docs/civilworks/mous/ferc_corps_30mar2011.pdf*).

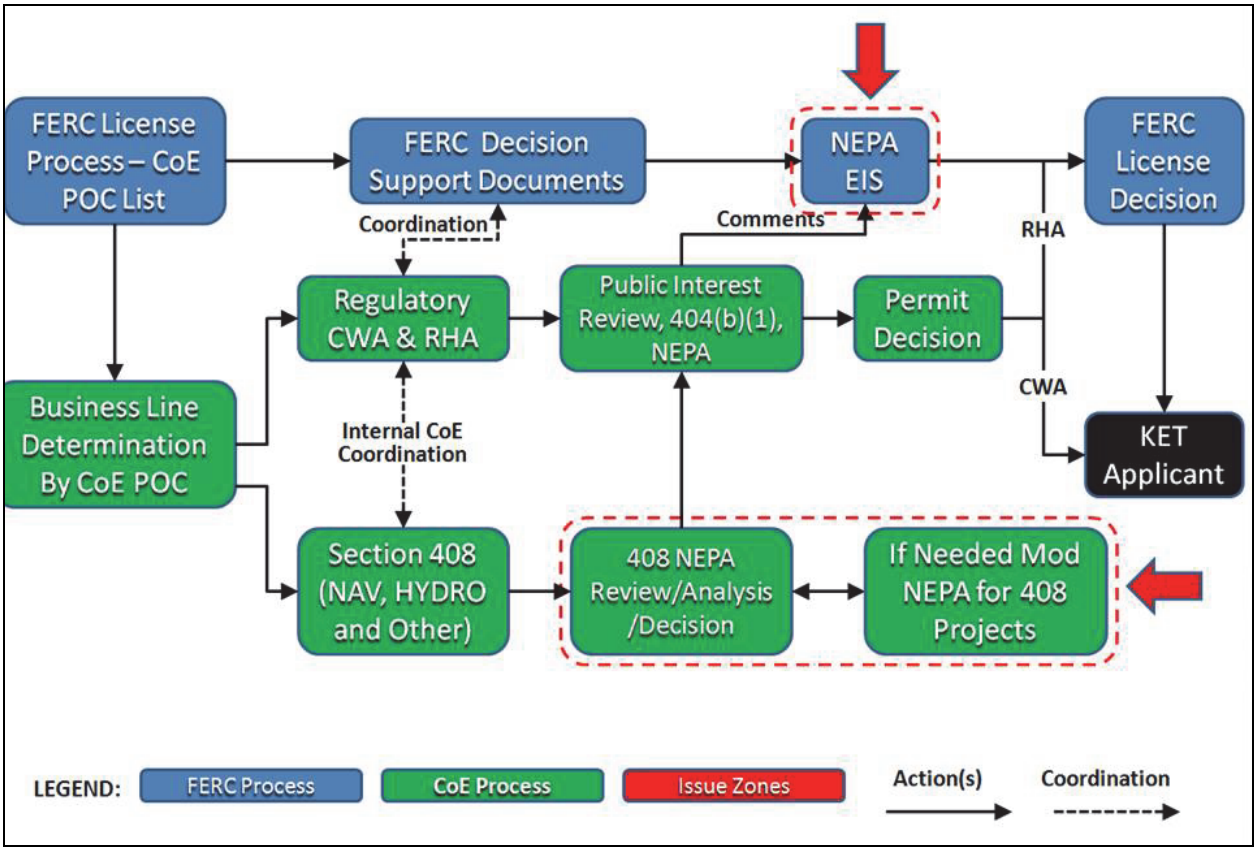


Figure 5. Simple box-and-arrow diagram summarizing joint FERC and USACE license and permitting process for KET development. Red arrows denote challenge areas for each agency. State of the science is presently inadequate to determine impacts of large-scale KET development with sufficient accuracy and precision to fully support NEPA analysis and decision-making. The same uncertainties over impacts also affect the ability of USACE to fully assess the effects of KET development on existing USACE Civil Works projects. The mission responsibilities of other agencies such as the Coast Guard, Fish and Wildlife Service, Park Service, etc. are not shown but must also be considered.

In its simplest form, the USACE response to a FERC request is as follows. FERC initiates contact through a designated USACE office for each district or division. From the perspective of USACE, support to FERC falls into either Regulatory or Civil Works business lines. From the Regulatory business line, a KET applicant may require either or both a Section 404 Clean Water

Act (CWA) Permit or a Section 10 Rivers and Harbors Act (RHA) Permit. For the successful applicant, the Section 10 RHA permit will be issued as part of the FERC Hydropower License and the 404 Permit will be issued directly to the applicant. In contrast, initial Section 408 activities are primarily internal to USACE as the agency assesses the effects of the applicants' proposed activities on existing Federal projects as part of a thorough public interest review. The completed assessment is communicated to FERC as formal comments to be included within the license documentation. Internally within USACE, the assessments are used to determine if impacts of the proposed KET are sufficient to invalidate existing EISs of affected USACE project(s). For example, extraction of a significant amount of kinetic energy from a river may decrease water velocity and increase the water elevation associated with flood flows. These changes to the geophysical environment may result in increased maintenance dredging and reduced flood protection in addition to numerous additional substantial impacts.

Day 2 conclusions differed in accordance with the business lines affected by KET development. USACE representatives in attendance felt that the Regulatory business line could generally discharge its responsibilities to FERC as required in the MOU. Regulatory is an existing USACE business line with a dedicated institutional infrastructure, established legal foundation, and a reasonably well-known set of information needs, tools, and procedures to support permit decision-making. The MVN and MVD representatives felt comfortable that their internal processes were generally adequate to discharge their responsibilities to support FERC and to conduct necessary internal coordination with regard to FERC support. MVD requires each of its districts to have a dedicated FERC POC and established lines of communication within the district to fully execute the "one door to the Corps" policy. This is very similar to MVN's typical review process, with the exception of the up-front addition of MVN's legal and public affairs staff. The consensus opinion was that the MVD process could serve as a template for a national process, although there is likely value in coordinating the MVN process with other USACE districts that have substantially different mission portfolios to more fully develop a national template for non-Federal KET development.

In contrast, Civil Works business lines may have less experience with how KET arrays potentially impact existing USACE investments. For example, a district like MVN, with no Federal hydropower projects within its boundaries, may not have experience with the suite of impacts associated with conventional hydropower projects or large-scale KET arrays. To adequately assess the potential impacts of KET on Civil Works investments, a team approach or access to outside support may be required (as required within MVD) to ensure that necessary expertise is available to support decision-making. To further complicate the Civil Works assessment, district boundaries for the Regulatory and Civil Works business lines may not be the same. Consequently, a large KET array located within the Regulatory boundary of one district may affect Civil Works investments in one or more additional districts.

In addition, the time and space scale of impact associated with KET arrays can be large. For example, as described in the presentations of the first day, large-scale KET arrays as proposed by Free Flow Power for the lower Mississippi River may have substantial impacts on geophysical and chemical patterns and biotic response for substantial distances in both the upstream and downstream directions that could affect large-scale USACE navigation, flood control, hydropower, and ecosystem restoration projects. This awareness led some participants to a

corollary question regarding the definition of a Corps Civil Works "project" on the Mississippi River. According to the Headquarters representatives, for navigable rivers such as the Mississippi River, the navigation project is considered the length of the mainstem river channel and port facilities that are maintained to meet authorized navigation specifications. Similarly, for flood control structures such as river levees, the flood control project is considered to be the entire mainstem river channel on which authorized levees are constructed, inspected, and maintained. Similar spatial definitions necessarily apply to ecosystem restoration projects, which inherently have large geospatial scales. For example, addition of KETs into an ecosystem restoration project such as LCA may profoundly affect the delivery of sediments upon which the success of the program depends. The group came to the realization that addition of a KET array and its likely large-scale effects into a system that already contains large-scale Civil Works projects will likely affect the Civil Works projects. Therefore, KETs have the potential to either reduce or enhance the performance of USACE Civil Works projects relative to the projections in the NEPA documentation.

The challenge for USACE to support national green energy policies can best be summarized from a NEPA perspective. FERC has primary responsibility for only a single EIS focused on KET development as proposed by a hydropower license applicant. This requires specific and well-defined inputs (i.e., comments and permits) from USACE. The completed EIS will form part of the support material for FERC license decision-making. From the USACE perspective, there are at least two NEPA documents that it must consider. The first supports the NEPA process necessary for FERC license deliberations. The second (or possibly more than two) is associated with existing Federal investments within the proposed KET impact boundary, which may be substantially larger than the project footprint and may extend outside district boundaries to affect one or more additional districts. Civil Works business line portfolios (the basis for the expertise of each district) vary across USACE districts and divisions, which further complicates development of consistent corporate support to KET development. For example, the districts responsible for providing input to the FERC hydropower license process may have little or no corporate experience with hydropower issues and impacts if Federal hydropower projects do not occur within the affected district boundaries.

Attendees generally found value in the workshop and expressed interest in future workshops to allow them to keep abreast of developing technologies and emerging issues. Although not discussed in detail because of time limitations, the attendees also supported the need for the kind of tools described during day 1 of the workshop and applauded technology coordination efforts with DoE scientists and engineers. Technology recommendations that follow in the next section will be based largely on Day 1 discussions combined with comments made during the first session of Day 2.

WORKSHOP RECOMMENDATIONS

The workshop generated a number of recommendations. For clarity, the recommendations parallel the structure of the workshop summary. Technology recommendations immediately follow this paragraph. Institutional process recommendations then follow and are separated into either Regulatory or Civil Works business lines.

Day 1- Technology Recommendations

Recommendation Day 1-A – Uncertainties in the fluid geophysical environment

Status Summary: Computational tools to address impacts of KETs on the fluid environment are relatively mature in their development, although there is uncertainty regarding the importance and magnitude of key physical processes (e.g., sediment transport and debris loading) in large rivers.

Recommendation: Corps engineers and scientists should coordinate (information exchange to active participation) with DoE staff, FERC, relevant agencies, and TEK developers in studies conducted to better understand and forecast impacts of KET development. Coordination should include international opportunities to access new technologies and databases. This coordination will allow USACE engineers and scientists to gain experience in tool selection and impact forecasting.

Recommendation Day 1-B – Targeted studies

Status Summary: Several uncertainties in the physics-based models prevent their routine application to address KET issues including scaling effects and small-scale hydraulic processes.

Scotlandville Bend would be an excellent site for a case-history study to address many of the impacts, technology needs, and institutional issues associated with KET development listed in this recommendation and others that follow.

Recommendation Day 1-C –Uncertainties in effects of KET support infrastructure

Status Summary: Many of the geophysical effects of KET construction, operation, and maintenance that could directly affect USACE projects are incompletely known (e.g., land structures such as transmission lines, buses, transformer fields, modifications to levees; KET construction and operation; and scheduled and emergency KET maintenance).

Recommendation: Participate in monitoring phase of DoE's adaptive management plan to describe and manage effects of KETs described on Day 1 to improve descriptions of effects of KETs on the fluid environment.

Recommendation Day 1-D- Need for Reference Models of the Fluid Environment

Status Summary: KET developers typically each have their own cadre of hydraulic modelers using individual, often proprietary, codes. Therefore, permitting agencies face a wide array of different, sometimes unfamiliar, codes whose output must be assessed as part of permit decision-making.

Recommendation: USACE engineers and scientists should collaborate with DoE to develop required attributes (e.g., dimensionality, spatial and temporal resolution, boundary conditions, and output requirements) of hydraulic models used to support KET license applications to improve permitting decisions and assessment of impacts on existing USACE projects.

Recommendation Day1-E – Application of Numerical Fish Surrogate Family of Models

Status Summary: Direct and indirect impacts on higher trophic levels are the greatest uncertainties in KET deployment and the most expensive to address. Several presenters mentioned ongoing or anticipated use of the NFS family of models developed by ERDC coupled to computational fluid dynamics models or detailed monitoring to help reduce uncertainty on KET impacts on higher trophic levels.

Recommendation: NFS models should be developed to improve the forecast accuracy of the effects of various KET designs or deployments.

Recommendation Day 1-F – Co-development of tools to improve forecast accuracy

Status Summary: FERC requires that some KET development be conducted in phases of increasing investment using basic concepts of adaptive management to systematically reduce uncertainties in license decision-making. DoE scientists and engineers use the opportunities provided by adaptive management to better understand impacts, build more accurate forecasting tools, and conduct focused studies to answer critical questions. Many of the uncertainties that plague KET from the DoE and FERC perspectives are also important to USACE, particularly for the Civil Works business lines.

Recommendation: USACE scientists and engineers should be hands-on participants or observers in the phased DoE Adaptive Management Program to help them understand and better anticipate the effects of KET development on existing USACE Civil Works projects.

Day 2 –Mission Status and Needs Assessment

Recommendations Day 2-A

The Regulatory business line is relatively experienced in dealing with KET institutional and technical issues. Consequently, recommendations to improve the ability of the Regulatory business line to support KET development are relatively modest in nature. In contrast, Civil Works business lines are less experienced in dealing with KET issues and, consequently, the recommendations are more comprehensive in nature. The red dashed lines of Figure 5 show the parts of the joint FERC and USACE FERC license process having the greatest engineering and ecological uncertainty (note that many other agencies are also involved but are not shown in the figure because this document focuses on the USACE perspective). Note that uncertainties about the impacts of KET development that limit the accuracy of the EIS for a license applicant will be similar to the uncertainties of KET development that plague existing USACE Civil Works investments. That is, similar uncertainties about possible impacts affect the missions of multiple agencies. Therefore, future efforts to reduce these uncertainties must be coordinated among the participants in the FERC license process.

Permitting Recommendation Day 2-A – Building a national USACE *template for KET development*

Status Summary: MVD and MVN have more experience than any other USACE division/district in dealing with KETs and FERC. This is because of their experience with the license application

of Free Flow Power for the lower Mississippi River. Other districts may have little or no experience in KET development.

Recommendation: Take advantage of the experience and processes established by MVD and MVN to build a national guidance document that will allow USACE to address Permitting and Civil Works business lines affected by KET development. This document may include a "tool" that describes the process from a USACE perspective including types of information required from the applicant as well as "triggers" to meet 408 requirements. The FERC Study Plan Determination for Free Flow Power could be a good starting point to develop a national template (*http://elibrary.ferc.gov/idmws/File_list.asp?document_id=13788453*).

Permitting Recommendation Day 2-B – Availability of advanced support to districts

Status Summary: Experience within MVD and MVN has shown that study requirements in support of a license or permit application may be unclear. In addition, studies prepared by the applicant to document the impacts of KETs can be complex and difficult to interpret.

Recommendation: Expertise should be available to districts from programs like the Dredging Operations and Technical Support (DOTS) Program or the Water Operations Technical Support (WOTS) Program to allow the districts to judge the adequacy of applicant studies. For example, MVN has an agreement with the Coastal and Hydraulics Laboratory at ERDC to review applicant documents.

Civil Works Recommendation Day 2-A – Improve district ability to respond to 408

Status Summary: While Regulatory requirements are clear within each district to respond to FERC requests, responsibility to meet 408 requirements is less clear. Oftentimes the USACE 408 POC is simply an office symbol (i.e., not an individual) and the appropriate response is unclear.

Recommendations: 1) Build a POC list within each district responsible for addressing 408 requirements. 2) Prepare a list of large-scale USACE Civil Works projects that includes a definitive description of project boundaries and the scale of critical geophysical, water quality, and ecological effects that can be matched to similar information from an applicant for a proposed KET project.

Recommendation Day 2-B

Status: Along with a few other districts, MVN has the most USACE experience in dealing with the institutional and technical issues associated with KET development. In comparison to other districts, MVN also has a reasonably clear vision in dealing with potential environmental impacts.

Recommendation: Take advantage of the technology and science uncertainties identified by MVN (and others that may be identified in the future) to build an R&D program that will identify many of the physics-based tools that already exist or develop new tools that provide critical information to decision-makers.

SUMMARY AND CONCLUSIONS: The national policy supporting development of renewable green energy affects several important USACE business lines, broadly separated into Regulatory and Civil Works. Although it can be improved, the Regulatory business line as it relates to KET is relatively mature and appears adequate to discharge its mission requirements. In contrast, the Civil Works business line has less experience with KETs, and both institutional adjustments and technology advancements are necessary to support the national policy. It is recommended that USACE consider developing a program to address these shortcomings. The program should be separated into technology advancement and institutional adjustment. Scientists, engineers, and regulators in affected agencies should coordinate their efforts to advance technology; this will avoid duplication of effort. Efforts should be supplemented with targeted R&D, as described above. Moreover, this phase of the program should include participation by multiple agencies in the adaptive management paradigm used by FERC to reduce uncertainties when making decisions regarding licensing. These same uncertainties affect USACE assessments, particularly with regards to Civil Works projects. The institutional adjustment portion of the program should include substantial participation by districts and divisions that have experience in KET to ensure that the USACE can corporately support renewable green energy development. These same districts should also participate in technology development efforts to ensure that selected technologies address issues from both the Regulatory and Civil Works business lines.

POINTS OF CONTACT: For additional information, contact David Smith (601) 634-4267, *David.L.Smith@usace.army.mil* or the manager of the Water Operations and Technical Support Program, Dr. Patrick Deliman, (601) 634-3623, *Patrick.N.Deliman@usace.army.mil.* This technical note should be cited as follows:

> Smith, D. L., J. M. Nestler, R. Styles, and B. Tetreault. 2014. *Analysis of the challenges and opportunities of hydrokinetic turbine development affecting the US Army Corps of Engineers.* ERDC WQTN-MS-08. Vicksburg, MS: U.S. Army Engineer Research and Development Center.
> *http://el.erdc.usace.army.mil/ansrp/ansrp.html.*

Appendix A: Workshop Attendees

Name	Agency	Contact Information
Brenda Archer	USACE-MVN (New Orleans District)	504-862-2046
Jeff Artman	USACE-MVK (Vicksburg District)	601-631-5577
Wayne Babcock	US Fish & Wildlife Service	
Stephen Bowler	Federal Energy Regulatory Comm.	202-502-6861
George Detweiler	US Coast Guard	202-372-1566
Mark Grippo	Argonne National Lab	630-252-3091
Beth Guynes	USACE-MVD (Mississippi Valley Division)	Now retired
Alex Haro	US Geological Survey	413-863-3806
Paul Hartfield	US Fish & Wildlife Service	601-321-1125
Ronnie Heath	ERDC-CHL	601-634-3592
Richard Jepsen	Sandia National Lab	505-284-2767
Jack Killgore	ERDC-EL	601-634-3397
Amy Klein	USACE-HQ	202-761-4559
Jeff Lillycrop	USACE-CHL/HQ	202-761-4229
Steve Maynord	USACE-CHL	601-634-3284
Bill McAnally	Northern Gulf Institute	662-325-9848
Vince Neary	Oak Ridge National Lab (now at Sandia National Labs)	505-284-2199
John Nestler	ERDC/BTS	601-634-2720
Howard Park	ERDC-CHL	601-634-4011
Rick Robertson	USACE-MVD	
Kamau Sadiki	USACE-HQ	202-761-4889
COL George Shepard	Deputy Commander MVD	
David Smith	ERDC-EL	601-634-4267
Richard Styles	ERDC-CHL	601-634-4065
Brian Tetreault	ERDC-CL	410-456-0417
Randy Thoreson	NPS	651-293-8450
Jeff Trulick	USACE-HQ	202-761-1380
Will Veatch	USACE-MVN	504-862-2858
Jim Walker	USACE-HQ	Retired
Mark Weiland	Pacific Northwest National Lab	509-427-5923
Timothy Wendt	US Coast Guard	Timothy.J.Wendt@uscg.mil
Rusty Wright	US Coast Guard	Rusty.H.Wright@uscg.mil
Pat Wycko	US Coast Guard	Patrick.D.Wycko@uscg.mil

Appendix B: Workshop Agenda

US Army Corps of Engineers®

U.S. Army Engineer Research and Development Center
Vicksburg, MS
Coastal and Hydraulics Laboratory

Ongoing Research and Development of Hydrokinetic Turbines: Evaluating Data Gaps Relevant to United States Army Corps of Engineers

Sponsor: CHL
Escort: Dr. Richard Styles

Wednesday, 29 February 2012

8:00 – 08:30 AM	Arrive Coastal and Hydraulics Laboratory	
8:30 AM	Welcome and ERDC Overview	Richard Styles
8:45 AM	USACE-HQ *"10-minute comments from business line managers"*	Jim Walker Kamau Sadiki Amy Klein
9:15 AM	Sandia National Laboratories *"National Lab Activities in Marine Hydrokinetics: Model Development"*	Richard Jepsen
9:45 AM	ORNL *"National Lab Activities in Marine Hydrokinetics: Testing & Environmental Studies"*	Vincent Neary
10:15 AM	**BREAK**	
10:30 AM	MSU *"Hydrokinetic Energy Effects on Navigation"*	William McAnally
11:00 AM	USFWS *"Habitat Association of Pallid Sturgeon in the Lower Mississippi River"*	Paul Hartfield
11:30 AM	ARGONNE *"Risk analysis of the Potential Ecological Impacts of MHK Arrays"*	Mark Grippo
12:00 PM	**LUNCH**	
1:00 PM	Tour Physical Models/Ship Simulator	Richard Styles
2:00 PM	FERC *"The FERC Hydropower Licensing Process, Hydrokinetic*	Stephen Bowler

Turbines, and Agency Coordination"

2:30 PM	USACE-MVN *"USACE New Orleans District Approach to Evaluating Hydrokinetic Projects"*	Will Veatch
3:00 PM	USCG *"Coast Guard's Roles and Responsibilities Concerning Alternative Energy Projects"*	George Detweiler
3:30 PM	**BREAK**	
3:45 PM	NPS *"Hydrokinetic Energy Projects & Recreation: A Guide to Assessing Impacts"*	Randy Thoreson
4:15 PM	PNNL *"Assessment of Fish Behavior and Vulnerability to Hydrokinetic Devices"*	Mark Weiland
4:45 PM	USGS *"Present and future USGS research on effects of Hydrokinetic Turbines on Fish Behavior, Injury, and Mortality"*	Alex Haro
5:15 PM	**ADJOURN**	

Thursday, 1 March 2012

8:30 AM	Corps-only meeting Recap Day 1, Planning our way forward What are the research and regulatory requirements needed for the USACE to adequately assess the impacts of KET? How should USACE proceed to incorporate these requirements?	Corps Participants
10 - 11:00 AM	Adjourn	

Innovation Solutions for a Safer, Better World!

Appendix C: Workshop Notes

US Army Corps of Engineers

U.S. Army Engineer Research and Development Center
Vicksburg, MS
Coastal and Hydraulics Laboratory

Ongoing Research and Development of Hydrokinetic Turbines: Evaluating Data Gaps Relevant to United States Army Corps of Engineers

Sponsor: CHL
Escort: Dr. Richard Styles

Wednesday, 29 February 2012

8:00 – 08:30 AM Arrive Coastal and Hydraulics Laboratory

8:30 AM Welcome and ERDC Overview Richard Styles

Dr. Martin welcome - there has been long time interest/work on alternative energy - at least from 1970's energy crisis.
Challenges - Concern with impeding navigation - taking into account water level changes; anchoring - different bottoms, changeable bottom, debris, sand waves; marking for navigation; connection to land - and how to get power where it's needed; optimal location for best velocity - but where scour is a problem.

Richard Styles - Corps overview; why are we interested in KET? - Proposals (e.g., Free Flow Power) may have an impact on waterways - 3-5% of river cross section.
Purpose:

- Present ongoing research by USACE and others
- Identify potential regulatory and permitting requirements for USACE and other's action
- Develop list of R&D needs to address unresolved navigation, flood risk management and environmental issues.

Introductions -

8:45 AM USACE-HQ - Business line managers

Jim Walker - Navigation BLM - lots of Inland and coastal navigation infrastructure - interested to see how KET can coexist with navigation. Taking into account need for dredging.

Kamau Sadiki - Hydropower BLM: not a new technology, but lots of developments. Corps the largest hydropower producer in the US - ~350 plants, lots of revenue - $1.5B back to treasury. Army policy - encourage non-Federal hydropower development. Challenges - 1st non-federal unit at Lock & Dam 2 in Minnesota. Want to make technologies modular - ability to easily modify, move as conditions warrant. Risks - Navigation, others as well - need to make sure developers do things responsibly an address risks. Need to make sure "all boxes are checked" regulatory, permitting, research, engineering. Want to take lessons learned from others - international as well.

Amy Klein - Regulatory program manager: USACE regulatory authorities:

- Rivers and Harbors Act - structures/work affecting Nvigable waters
- Clean Water Act - discharge of dredged/fill material into US waters (not just navigable)
- District Commanders permit decision making

FERC has lead on KET - USACE cooperating agency - MOU, comment on documents

Permit type - Individual vs. general
Coordination with USACE Navigation and Hydropower
Challenges - Competing interests - public interest - many aspects and impacts to be assessed, understood and mitigated.

9:15 AM Sandia National Laboratories Richard Jepsen
"National Lab Activities in Marine Hydrokinetics: Model Development"

- Main focus on model development
- Program mission - Research, test and develop innovative water resource energy generation
- Wave energy, tidal currents, free flowing rivers - potential for generation
- Focus - determine potential, address environmental challenges, demonstrate performance; identify cost drivers - make commercially viable.
- Main areas of SNL work: Model development, research tools, environmental impacts
- CACTUS Code - single device turbine analysis - provides power vs. current speed curves
- High performance turbine blade design
- Modeling acoustics - predictions for environmental impacts
- Environmental fluid dynamics code (EFDC) - large scale hydrodynamics:
    - evaluate if can be used for evaluating MHK affects
    - modify to provide more realistic output - momentum sink.
    - Can be used for single device and also for arrays of multiple devices.
    - Help determine optimum spacing of devices.
    - Various configurations can be compared.
- Often end up "chasing the flow" as devices are deployed - affect flow
- Wave device modeling - Modeling to determine effect of devices on wave patterns
    - Different from flow modeling - different amplitudes and frequencies of waves
    - Monterey Bay model
    - Similar evaluations of spacing, configurations.
    - Scale model tests with Oregon State Univ. -
- Miss River environmental studies - Scotlandville bend - look at current changes, changes in bottom and bank sedimentation, etc.
- Quantifying effects of altered flow around array - both across river and above and below turbine. Affects navigation, bank and bottom stress, erosion rates - model can inform environmental sampling plans.
- Environmental study - Cobscook Bay - affect on migration of baby scallops
- SF Bay - tidal case- evaluate effect of array on flushing of water in the Bay - even at relatively long distances from array.
- Hawaii wave testing - just beginning
- Reference models - develop a set of models to develop baseline cost of energy and identify cost reduction pathways. Generic designs and resources (sound, river, waves) base on real data. Will be in public domain - allow others to develop tools, designs
    - Cost drivers - maintenance, installation, permitting, infrastructure, device - ID pathways for improvements - lower costs, more power
- Questions:
    - power capacity - how relate to other sources? 20% development of potential may = 6% of US energy needs. But estimates are uncertain
    - Details on array modeled in river - not real river - generic model. Observation that ship effects "happen every day" - possibly more than KET impacts.

9:45 AM ORNL Vincent Neary

"National Lab Activities in Marine Hydrokinetics: Testing & Environmental Studies"

- Technology performance testing - supporting model validation
- Not just machine performance - also environmental impacts - recognize multiple stakeholders
- Assess resource potential - theoretical, technical and practical.
- Many technologies - need to be advanced to test and assess
- Assess environmental impacts: physical, water quality, environmental
- Need to be able to assess survivability of devices
- Cost of Energy = Cost (of manufacturing, installation, O&M, etc.)/Annual Energy Production (AEP)
    - Need to develop a standardized calculation to allow for comparisons among technologies an other energy sources.
- Lab testing - using large flume at St. Anthony's Falls to be able to test arrays
- Objectives:
    - Validation data sets
    - Tech Readiness level (TRL) and ERL assessment
    - COE assessment
    - Best practices for lab and field testing - e.g., ship-mounted ADCPs issues with moving sensors
- Experiment set up - device, multiple sensors - ADVs, PC-ADPs - upstream and downstream from device
- Outputs:
    - Performance curve - operating efficiency vs. tip speed ratio
    - Inflow and wake flow measurements - includes "wake recovery" after flow through device
    - Inflow and wake turbulence measurements - effects on environment and on other turbines
- Validation - of SNL-EFDC code using flume test data
    - Some differences based on flume constraints - width
    - Future work - additional device types.
- Full-scale field testing - Scotlandville bend - Miss. River
    - Free Flow energy device
- Identifying a lot of knowledge gaps:
    - MHK resource: machine specs, siting constraints
    - Technology readiness: Survivability, wake effects on spacing
    - Environmental readiness: Fish-machine interaction, physical impacts of wakes, EMF, noise
    - COE drivers: Spacing, Maintenance costs, permitting and monitoring

10:15 AM **BREAK**

10:30 AM MSU William McAnally

"Hydrokinetic Energy Effects on Navigation"

- Number of preliminary permits issued - inland and coastal
- "Can navigation and HKE coexist?"
- Potential effects:

    - Visual navigation, electronic navigation, response (SAR, pollution, etc.), cirrents, navigation safety - allision and collision
- Many benefits of HKE but also need to be clear-eyed of downsides
- Simulated passes through turn- vessels stray out of channel
- Probability of vessel excursion from channel - intentional and inadvertent
    - Also vertically - vessels load as much as possible, squat, heel and trip effects
    - Cannot be ignored - historical info on probability of excursions
- Physical effects - hypothetical waterway
    - Compare baseline with energy extraction due to HKE devices
    - 10% KE =~2% total energy; however increases with increased number of devices.
    - Even more for stress and transport - square, cube and 4^{th} powers
    - Cumulative, upriver to next control point.
- Expected physical effects - will vary site-to-site:
    - Decreased flow
    - Altered water levels
    - Increased sediment deposition
    - Altered salinity (in estuaries)
    - Scour at structures with downstream deposition
- Conclusions:
    - Contribution, but potential drawbacks
    - Multidimensional modeling of sites is required
    - Cumulative impacts of multiple installations (e.g., 1000s in river) need to be considered.

11:00 AM USFWS Paul Hartfield

"Habitat Association of Pallid Sturgeon in the Lower Mississippi River"

- 3 endangered species in Miss. River - sturgeon, tern, mussel.
- USFWS concerns with HKE:
    - Lack of knowledge of composition and abundance of aquatic specis affected by projects
    - Turbine entrainment of species
    - EMF effects - sturgeon and other species detect EMF
    - Noise
    - Geomorphic effects - may affect O&M of navigation system
- Range of Pallid Sturgeon - Lower Miss and Missouri River
- Annual "take" was as low as 1 fish/year - could be a showstopper - many turbines could easily reach jeopardy level
- Better data on fish abundancy has allowed higher takes - ~1,500/year
- Track fish with acoustic tags
- Have quantified various habitats - different parts of rivers (e.g., point bars, crossovers, etc.) and breakdown where fish are based on location; also other factors (water temp)
- Potential effects of HKE on sturgeon - study plan, not fully funded:
    - Collect, measure and tag
    - Collect additional data
    - Monitor fish for 2-3 years
    - Sites - FFP sites: Tunica, Vicksburg, Baton Rouge; several control sites
    - Analysis - compare data by species, reach, season, river stage and other variables
    - Pre-HKE development baseline

11:30 AM ARGONNE Mark Grippo

"Risk analysis of the Potential Ecological Impacts of

MHK Arrays"

- Argonne's role - take data from other studies and funnel into risk assessment
- ID highest risk impacts
- Data gaps to be investigated
- Suggest new research areas
- Using EPA risk assessment protocol
    - Problem formulation
    - Analysis
    - Risk characterization
- Conceptual model development
    - Review existing literature
    - Review by managers
    - Very little data; much speculative
- Need to consider:
    - Incremental impact increase from single to array
    - Impact of other stress factors
- Problem formulation:
    - Have captured complex array of factors to consider - diagrams in presentation
    - Existing anthropogenic stressors in addition to MHK - need to determine what role MHK will play, and comparison to existing. - Cumulative impact
    - Barriers - little info exists, inconclusive results, need to understand incremental increase to do cumulative analysis.
- Analysis:
    - Characterization of exposure
    - Characterization of ecological effects
    - Modeling interactions with MHK devices
        - Determine exposure (blade strike, noise)
        - Determine behavioral effects (avoidance, etc.)
    - Empirical and mechanistic models
        - Final product visual simulation, forecast fish trajectories - aid in design of arrays/devices to minimize impact.

12:00 PM **LUNCH**

1:00 PM Tour Physical Models/Ship Simulator — Richard Styles

2:00 PM FERC — Stephen Bowler

"The FERC Hydropower Licensing Process, Hydrokinetic Turbines, and Agency Coordination"

- Hydropower program - licensing, dam safety, license administration and compliance
- Issuances:
    - Preliminary permits - don't permit anything - allow developer to keep site while preparing for authorization; feasibility studies, etc.
    - Licenses - authorize construction and operation
    - Exemptions - 5 MW, Conduit
- Licensing processes - Integrated, Traditional and Alternative
    - ILP is default
        - Pre-filing: initial proposal, scoping meetings, study plan development - conduct studies.

        - Post-filing: Application: proposal and mitigation measures, FERC and public review, FERC env. document, FERC authorization (License order)
    - Process - about 3 years
- Licensing standard:
    - Equal consideration to power and environmental users within waters of US.
    - Authorize projects that best serve public interest.
- Other agencies - USFWS, NOAA, State gov'ts, USCG
- To allow for real world testing, have some limited issuances for non-grid and limited grid connected testing
    - May still require authorizations from other agencies
- Pilot project license
    - Small, short term, removable
    - Test technology, evaluate sites
    - Protect environment - short term, monitoring, shutdown if harm
    - Processed in as little as 6 months
    - Abbreviated pre and post filing tasks
- 97 preliminary permits issued (tidal, wave and inland)
- 61 pending projects
- 2 pilot licenses issued
- Work with other agencies
    - Agreement with USCG - working on nationwide MOU
    - MOU with USACE
        - Coordinate review
    - Rivers and Harbors Act - Corps requirements met through licensing process
    - FERC is lead agency
- "Orange book" (formerly "Salmon") - outlines all three licensing processes and exemption process
- No fee for license process; but once license issued there is a fee for regulation

2:30 PM USACE-MVN Will Veatch

"USACE New Orleans District Approach to Evaluating Hydrokinetic Projects"

- MVN regulatory process
    - DA permits - Rivers & Harbors Act; Clean Water Act
    - Hydrokinetic project permit process
        - Pre-app consultation
            - FERC lead agency
            - Establish MVD formal review team, members from multiple disciplines
        - Application submission
            - USCG and FERC process workshop
            - FERC and USACE permit coordinated submittal
        - Permit review
            - Same as regular permit process
        - Permit decision
            - FERC license includes
- Areas of concern:
    - Water quality - mainly leakage of lubricants, etc.
    - Wetlands - impact to riparian wetlands - mainly with getting power from turbines and maintenance/support activities.

    - Fish and wildlife - impacts in entire project area - all, not just threatened and endangered, also not just aquatic.
    - Navigation
        - Low water hazards
        - Altered river currents
        - Traffic during installation/maintenance
        - Altered sedimentation patterns
            - May lead to hazards and currents
            - Have set up team at ERDC-CHL to evaluate submissions by applicants
            - Effects on shipping channels
            - Dredge access
            - Local and cumulative effects
        - Flowline - water surface will rise if velocity goes down
            - Need to determine what this will be - effect on levees, etc.
            - Construction between levee and river (batture) - impedes flow at high water
        - Channel stability
            - Revetment integrity, access to failure areas, altered currents, levee loading during construction, power line impacts on levees
- Conclusions:
    - Support HKE, provided concerns are addressed
    - Work closely with FERC
    - Many concerns remain to be addressed
    - MVN's Hydrokinetic Project Team and Independent Technical Review Team address concerns and technical validity.

3:00 PM USCG George Detweiler

"Coast Guard's Roles and Responsibilities Concerning Alternative Energy Projects"

- USCG main purpose - safety of navigation
    - Not just commercial - recreational as well
- USCG involved if in Navigable waters of US
    - Work with whoever is lead agency - FERC, BOEM, USACE, NOAA - depending on project, location, etc.
- USCG authorities come from the Ports and Waterways Safety Act
    - Navigation, vessel safety
- Cooperating agency
    - May develop recommendations to provide for safety of navigation
    - Safety measures - routing measures
    - Minimize impacts on other CG missions - SAR, environmental protection, security
    - Private Aids to Navigation (PATON) may be involved
- USCG will not approve or disapprove a project or issue a permit
- Criteria USCG considers
    - Site location
        - Traffic - types, uses
        - Navigation Safety risk assessment - but still don't know what the "acceptable number" is
    - Structure - risk of collision, clearances, impact on SAR and MEP, Security
    - Navigation and collision avoidance

        - Currents/tides
        - Weather
        - Visual navigation
        - Communications
        - Radar
        - Markings
    - Mitigation measures
        - Charting, routing, exclusion zones, monitoring, shutdown procedures
    - Acceptable navigational risk?
        - Increased vessel density
        - Mix of vessel types
        - Allision risk
        - Traffic patterns, routing measures
        - Economic impact
    - 3rd dimension
        - Underkeel clearance
        - Towing catenary
        - Anchoring
        - Fishing
        - Recreation
- Some question about USCG role in working directly with proposals - probably limited to PATON, evaluation of safety zones, routing measures, operations associated with construction.
- "3rd dimension" - air as well - make sure that's considered - FAA's role?
    - Electric transmission towers
- Commonality of technology and studies different agencies are using - is it available to other agencies for their use in the regulatory process?

3:30 PM **BREAK**

- Richard Jepson comment - concern with interpretation of what he had presented earlier - large alterations of flow are possible but not likely as for performance of device you will want the result to be as close to the same as possible. Optimizing for performance and for environment impact often converge

3:45 PM NPS Randy Thoreson
"Hydrokinetic Energy Projects & Recreation: A Guide to Assessing Impacts"

- NPS perspective on HKE
- Authorities:
    - Federal Power Act
    - Wild and Scenic Rivers Act of 1968
    - Outdoor Recreation Act of 1963
- DoE report to Congress in 2009 on MHK did not cover social and recreation impacts (land use, aesthetics)
- Hydropower Reform Coalition - website with good information
- Publication- "HKE Projects and Recreation" - 2011
    - Types of projects
    - Types of recreation
    - Concepts for assessing impacts
    - Potential impacts on recreation

    - Types of studies for recreation impacts
- Held workshops in Memphis and Portland - 2011
    - Agencies, Free Flow Power, others
- Facilities, activities, use levels - but also experiences
- Recreational opportunities spectrum - "primitive to paved"
    - Can be quantified by recreational use
    - Direct and indirect effects, short term/long term
- Scale and cumulative impacts
    - Other development and uses
    - Other potential restrictions
- Progression of study effort
    - Desktop & secondary sources
    - Limited studies
    - Intensive studies
- Protection & Mitigation strategies
    - More vs. less sensitive areas
    - Reduce impacts (project modifications)
    - Mitigation - trade offs
- Variety of river recreation activities
- Considerations
    - Aesthetics - viewscapes and soundscapes
    - Similar to what others have mentioned, but slightly different from perspective of recreation.
- Integrate early and often - start as soon as you can
    - Reach out to stakeholders:
        - Non-gov't groups - e.g., Mississippi Wild Miles, clubs
        - Property owners
        - Local govt's
        - Business community
- Recreation (including aesthetics and land use), as it related to hydrokinetic projects, can be recognized and evaluated in a systematic way.
- NPS main focus: recreational access and safety

4:15 PM PNNL Mark Weiland

"Assessment of Fish Behavior and Vulnerability to Hydrokinetic Devices"

- Hydrokinetic "stress:"
    - Trauma, altered behavior, change in migration patterns, dispersion
    - Survival - immediate and delayed mortality
    - Long-term effects - reproduction, population structure, community interactions
- Acoustic monitoring
    - Variety of uses (sound, monitor behavior, characterize environment), variety of capabilities - no "one size fits all"
- JSATS - use for fish monitoring
    - Use to track where fish go, and their survival rate
    - Receiver arrays ashore (mounted to structures) or tethered underwater - collect data on board then download when retrieved.
    - 300m detection range - greater in quiet waters
- Variety of systems that can be used for a wide variety of purposes - different capabilities, appropriate for different animal monitoring, locations, etc.

- Recommend baseline monitoring prior to installation of devices - reference level for subsequent changes
- Compromises with technology - need to identify what works best for specific application.

4:45 PM USGS Alex Haro

"Present and future USGS research on effects of Hydrokinetic Turbines on Fish Behavior, Injury, and Mortality"

- S.O Conte Anadramous Fish Research Lab (CAFRL)
- HKT testing:
  - Hydraulic and mechanical
  - Biological - impacts on fish,
  - (others)
- Various types tested in flume
- Specific Encurrent EN-005 test
- Different fish effects:
  - Strike, avoidance, delay, disruption of schooling
- Observations:
  - - underwater video - some constraints
  - PIT telemetry
  - 3D acoustic telemetry
- Did control condition as well - turbine out of water
- Evaluated survival rates - short term and long term
- 2D tracks of fish
- Free Flow Power turbine tests:
  - Grapefruit and fish
  - Some strike indications
- Plans for tests in 2012
  - More turbine tests as before
  - Larval strike/shear testing
- Challenges:
  - Many designs - results for one may not apply to another
  - Fast vs. slow blade speed
  - Lab vs. field evaluations - differences?
  - Identification and quantification of effects
- May be able to do a lot through modeling
- Need to decide on limits, metrics, thresholds
- Questions:
  - Consideration for FFP to use screen to prevent fish entry? - no, too much loss of efficiency
  - Difference between shrouded and non-shrouded turbines on fish mortality? Too early to tell

Main points

- Multiple agencies have roles and responsibilities
- There is some coordination between agencies (FERC, USCG and USACE)
- Common areas of concern were outlined
- All support hydrokinetic energy development, but need to be aware of and address concerns

- Different agencies have different roles in the approval process - agencies should coordinate efforts and share information, technology, studies.
- There are many considerations when evaluation HKE projects - some obvious (safety) some not (recreation, aesthetics)
-

5:15 PM **ADJOURN**

Thursday, 1 March 2012

8:30 AM Corps-only meeting — Corps Participants

Recap Day 1, Planning our way forward

What are the research and regulatory requirements needed for the USACE to adequately assess the impacts of KET?
How should USACE proceed to incorporate these requirements?

- Approach by developer - what's our response?
  - "One way street" - i.e. they provide us information? Or dialog - they provide, we ask for more, etc.?
- USACE involvement with FFP came through FERC process
  - Made concerns known through response to documents provided
- Pilot projects -
- Each district has a FERC coordinator - main conduit for information - not directly from applicant. However each District different
- If KET installation will be a modification to a Corps asset (levee, channel, structure, etc.) requires 408 permit (?)
- 208 permit process - smaller scale, approval by Dist. Engineer - need to clarify line between 208 and 408
- Need for standardization/coordination between Corps Hydropower, Navigation, Civil works, regulatory, etc. offices?
- Need to be able to identify and act on "triggers" for Corps permitting ativity - 408
- "who defines what is the project" - example of FFP - various sites, across Districts, changes year-to-year - how handle this?
- Good starting point - FERC's study plan for FFP
  - Captures a lot of USACE concerns
  - Applicable to Miss. River - may be other issues for other locations - PNW, New England
- Is there a way to scope the basic information required for any project? Rather than "rock management"
  - Difficult - need to know impacts before can tell what is needed - applicant provides this
- Research issues -
- Possible to have a "checklist?" -
- Jeff - is there an "EC" (?) on this that can provide guidance?
- [John's suggestion for a "tool" to use when contacted by potential applicants]
  - Lay out coordination required, process/steps, information needed, etc.
  - Triggers - e.g., for 408 approval
- Jeff - didn't hear a lot about impact on river on KET devices - and if they are impacted what is subsequent impact on Corps structures/waterways/etc.?
  - "Damaged turbine recovery study" -
- From Will Veatch:

    - FYI, here is FERC's Study Plan Determination for Free Flow Power. This might provide a starting point for a skeleton list of common issues to investigate for KET projects, at least for riverine projects in big rivers.
    - http://elibrary.ferc.gov/idmws/File_list.asp?document_id=13788453
- "Really need to answer the 408 question - determination of whether it applies or not."
    - As early as possible
    - May need to ask lawyers

Ronnie Heath - R&D needs

- Scotlandville bend proposal - lots of turbines
- How will we address questions private developers don't have capability to determine?
- Cannot easily scale up single turbine model to array
- Need for physical model to validate numerical models
- Need to break into smaller steps - can't go from 1 unit to many - either for evaluation or for deployment
- Is there a requirement for monitoring once units are deployed? What are Corps requirements for monitoring?
    - In Corps permits there are monitoring requirements - District responsible for this and determination of action if monitoring shows need (e.g., removal of units)
- Based on risk - on our interest to move slowly - incremental - e.g., percentage of total desired deployment
-

10 - 11:00 AM Adjourn

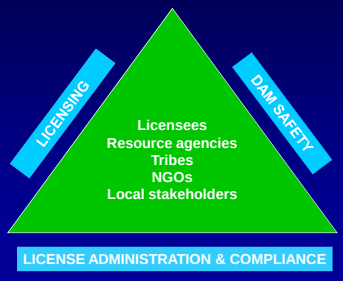
Appendix D: Workshop Slides

Marine and Hydrokinetic Energy, FERC and the U.S. Army Corps of Engineers

Vicksburg, MS
29 February 2012

Federal Energy Regulatory Commission

Hydropower Program



Types of Issuances

- Preliminary permits
  - Maintains priority of application for three years
  - Conduct feasibility studies and prefiling activities
  - Does not authorize construction
- Licenses
  - Authorizes construction and operation
- Exemptions
  - 5 MW
  - Conduit

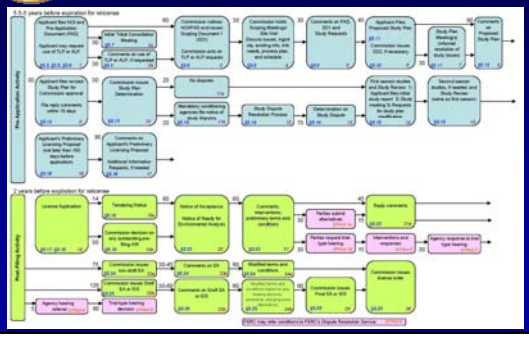
Commercial Project License

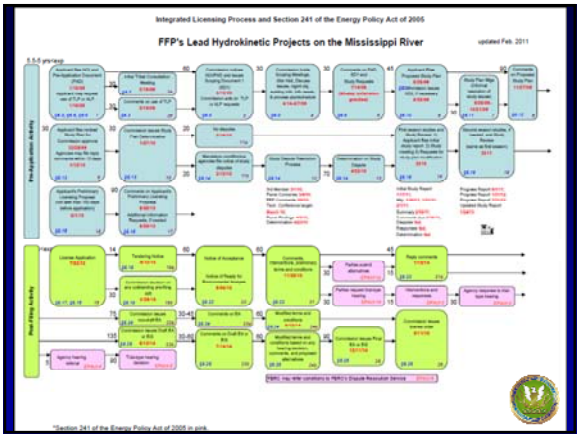
- Integrated Licensing Process (ILP)-default
  - Traditional Licensing Process (TLP)
  - Alternative Licensing Process (ALP)

Prefiling	Postfiling
• Consult with interested parties on issues and studies • Gather information • Conduct studies • Prepare license application	• Seek comments from interested parties • Prepare EA or EIS and seek comments • Weigh all information in record before Commission decision

Integrated Licensing Process

Integrated Licensing Process





Hydropower Licensing Standard

- Federal Power Act – FERC licenses must:
  - Give equal consideration to power and environmental uses within waters of the U.S.
  - Authorize projects that best serve the public interest

Distributed Decision Making

U.S. Fish & Wildlife Service
-Endangered Species Act
-Migratory Bird Treaty Act

NOAA
-Fssential Fish Habitat
-Marine Mammal Protection Act
-Endangered Species Act

State Review
-Coastal Zone Management Act
-Clean Water Act
-National Historic Preservation Act

U.S. Coast Guard
-Ports and Waterways Safety Act

Regulatory Approach

- Recognizing the conundrum of need for real-world testing, yet limited information to prepare applications the Commission has tailored its existing program to meet the needs of new technologies:
  - Preliminary permits
  - Device testing (no grid connection)
  - Pilot project license (grid connection)

Device Testing (no FERC license)

Verdant Power, LLC
April 2005

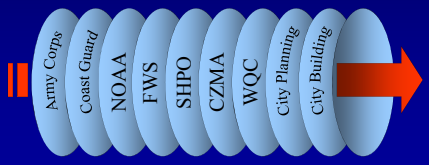
- **Short term deployment**
- **No grid connection**

Maine Maritime Academy
March 2010

- **Experimental technology for purpose of preparing a license application or for educational purposes**

Device Testing
(no FERC license)

Other authorizations may still be needed



Pilot Project License

- Small, short term, removable projects
- Test technology and/or evaluate sites
- Protect the environment
  - Short license term and small footprint
  - Post-license monitoring
  - Project shutdown or removal if harm
- Process license applications in as few as 6 months

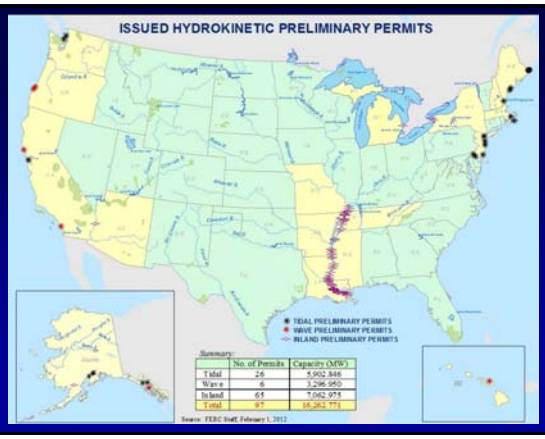
Pilot Project License

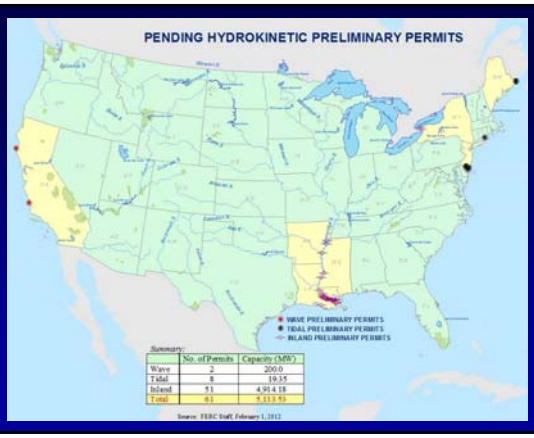
From the Integrated Licensing Process (ILP)

Guidance and Checklist available at www.ferc.gov

Prefiling	Draft License Application and Waiver Request	Comments on Process/DLA/ Monitoring Plans	Public Meeting (if needed)	FERC Determination on Waiver Request
Postfiling	Application Filed	REA Notice	EA	FERC Authorization (License Order)

4.5 months — 1.5 – 3 months



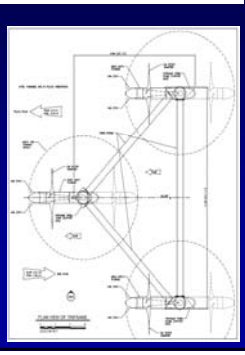


Wave & Hydrokinetic Projects

(as of February 1, 2012)

- Issued preliminary permits: : 97 (16,263 MW)
  - 26 tidal, 6 wave, 65 inland
- Pending preliminary permits : 61 (5,133 MW)
  - 8 tidal, 2 wave, 51 inland
- Projects in pre-filing for license: 79 (8,687 MW)
  - P-12743 Douglas County (OR) Wave Commercial 3.0 MW
  - P-12749 Coos Bay (OR) Wave Commercial 100 MW
  - P-12665 East River (NY) Tidal Pilot 0.2 MW
  - P-12679 Cook Inlet (AK) Tidal Pilot 5.0 MW
  - P-12690 Admiralty Inlet (WA) Tidal Pilot 1.0 MW
  - P-12829 et al. Mississippi River Projects In-River Commercial 70 projects 7,883 MW
  - P-13015 Muskeget Channel (MA) Tidal Pilot 5.0 MW
  - P-13305 Whitestone Poncelet (AK) Tidal Pilot 0.1 MW
  - P-13509 Turnagain Arm (AK) Tidal Commercial 240 MW
  - P-13679 San Onofre Electricity Farm (CA) 450 MW
- Projects in post-filing for license: 2 (1.8 MW)
  - P-12711 Cobscook Bay (ME) Tidal Pilot 0.3 MW
  - P-12713 Reedsport OPT Wave Park (OR) Wave Commercial 1.5 MW
- License issued for pilot project: P-12611 Roosevelt Island (NY) Tidal Pilot 1.05 MW
- Amendment issued: P-4306 Hastings Commercial In-River 0.07 MW

RITE Project (P-12611)



RITE Project (P-12611)
Path to License

- February 28, 2007 – Commission issues scoping document
- March 27 & 28, 2007 – Commission holds scoping meetings
- Between 2007 and 2009 – Verdant deploys 6 turbines in East River under "Verdant Exemption"
- December 29, 2010 – Verdant files license application
- May 3, 2011 – Commission issues EA
- December 12, 2011 – New York DEC issues 401 WQC
- January 23, 2012 – Commission issues 10-year pilot license
  - > thirty 35-kW turbines installed in 3 phases (1,050 kW)
    - year 1 – 3 turbines
    - year 3 – 9 additional turbines
    - year 5 – 18 additional turbines

RITE Project (P-12611)
License Requirements

- Safeguard Plans
  - Public Safety and Emergency Shutdown Plan
  - Navigation and Safety Plan
  - Project Removal and Site Restoration Plan
- Aquatic Environment
  - Record water velocities and water surface level data
  - Underwater noise monitoring and evaluation plan
- Aquatic/RTE Species
  - Hydroacoustics Monitoring Plan
  - DIDSON Monitoring Plan
  - Species Characterization – Netting Plan
  - Tagged Species Detection plan
  - RTE species monitoring

RITE Project (P-12611)
License Requirements

- Birds
  - Bird Observation Monitoring Plan
- Recreation
  - Recreation use monitoring
  - Install public informational displays
- Aesthetics
  - Design specifications to minimize aesthetic impact
- Cultural Resources
  - Consultation regarding unanticipated discoveries of cultural resources

Cobscook Bay Project (P-12711)

Cobscook Bay Project (P-12711)
Path to License

- 2010 – ORPC Maine deploys one barge-mounted turbine in Cobscook Bay under "Verdant Exemption"
- September 1, 2011 – ORPC Maine files license application
- January 4, 2012 – Commission issues EA
- January 31, 2012 – Maine DEP issues 401 WQC
- February 28, 2012 – Commission issues 8-year pilot license
  - > five 60-kW turbines installed in 2 phases (300 kW)
    - year 1 – 1 turbines
    - year 2 – 4 additional turbines

Cobscook Bay Project (P-12711)
License Requirements

- Safeguard Plans
  - Project Operations and Monitoring Plan
  - Project Inspection and Maintenance Plan
  - Project and Public Safety Plan
  - Navigation Safety Plan
  - Emergency Shutdown Plan
  - Project Removal and Site Restoration Plan
- Aquatic Environment
  - Hydraulic Monitoring Plan
  - No pile driving activities between April 10 and November 7 of any year
  - Acoustic Monitoring Plan
  - Benthic and Biofouling Monitoring Plan

Cobscook Bay Project (P-12711)
License Requirements

- Aquatic/RTE Species
  - Fisheries and Marine Life Interaction Plan
  - Marine Mammal Monitoring Plan
- Birds
  - Bird Monitoring Plan
  - FWS' *Bald Eagle Management Guidelines*
- Recreation
  - Install public informational displays
- Aesthetics
  - Design specifications to minimize aesthetic impact
- Cultural Resources
  - Consultation regarding unanticipated discoveries of cultural resources
- Adaptive Management
  - Adaptive Management Plan

Free Flow Power Mississippi

- 11 studies approved in Commission's study plan determination (issued 1/27/10)
- Studies designed to gather data to meet agency information needs (e.g. NVIC)
- Study progress reports & comments
  - Commission's last set of comments issued 11/10/11
  - FFP's Fifth study report filed 1/31/12
  - Two more progress reports before Preliminary Licensing Proposal is due (target 3/1/13)
  - Anticipating FFP request for schedule adjustment

Free Flow Power Mississippi

SECOND QUARTER REPORT – JULY 31, 2010 (file with consultation record since First Quarter Report)

Study	Requirements
1. Infrastructure Siting Study	1. Results of competing use analysis, barge-mounted screening analysis, and updated results of piling-mounted screening analysis. Uncertainties and data gaps should be specified. This may include the need for field bathymetry survey data if existing data are inadequate. This may also include the need for borings to assess the suitability of substrates for piling-mounted structures. 2. Final detailed plan for the experimental test deployment of four or more pilings with mock or prototype turbines and one barge with one or more mock or prototype turbines.
2. Hydraulic Study	1. Plan for documenting hydraulic and sediment conditions before during the test deployments. 2. Integration of data such as bathymetry from other sources. 3. Detailed field data collection including velocity and water level data in specific project locations. 4. Near-final near-field model with enough detail to allow review by the Corps and other interested agencies. 5. Initial mid-field and far-field river model with enough detail to allow review by the Corps and other interested agencies. 6. Synthesis of hydraulic data on debris (including logs and ice). 7. Final plan for evaluation of potential effects of vibration on Corps' structures.
3. Navigation Study	1. Completed baseline data and information on traffic and navigation. 2. Preliminary design of turbine mounting structures and infrastructure installation approaches.
4. Damaged Turbine Recovery and Debris Risk	1. Preliminary assessment of risks to turbines. 2. Identification of recovery approach options.

Letter of Understanding (LOU) – USCG & FERC
Free Flow Power Mississippi ILP Sites

- Commission is lead agency for NEPA
- Coast Guard is navigation safety & security subject matter expert
- Coordinate comments on study reports & analysis in NEPA documents
  - USCG sector comments consolidated
- Communications with Free Flow Power & other stakeholders
  - USCG technical advice for Free Flow Power
  - FERC/ USCG deliberations & merits of the projects

Corps – FERC MOU Purpose

- Coordinate regulatory review processes
- Establish framework for early Corps participation in Commission licensing processes
- Ensure timely review and action on non-federal hydropower development

Statutory Overview

- National Environmental Policy Act
- Rivers and Harbors Act
- Clean Water Act
- Marine Protection, Research and Sanctuaries Act
- Federal Power Act

Roles and Responsibilities

- Rivers and Harbors Act
  - Affirms that the Corps' section 10 requirements are meet through the licensing process
  - Section 4(e) of FPA is the venue for fulfilling this responsibility

Roles and Responsibilities

- Clean Water Act
  - Coordinates Corps' section 404 permit review with Commission's license application review
  - Maintains independent decision making authority

Coordination Commitments

- Encourage joint scope of analysis suitable for Corps and Commission decision making
- Encourage joint purpose and need statement to fulfill each agencies' requirements
- Encourage adoption of joint schedule for decision making

Coordination Commitments

- Coordinate safety inspections
- Describes each agency's role for safety inspections of Corp facilities and Commission licensed facilities
- Avoid duplication of effort for inspections

What does it mean?

- Commission is lead agency
- Use Commission's NEPA scoping process
  - Use ILP schedule
  - For other processes consult in establishing NEPA milestones


Questions?
Contact: Stephen Bowle
(202) 502-6861
stephen.bowler
www.ferc.gov

COAST GUARD'S ROLES AND RESPONSIBILITIES CONCERNING ALTERNATIVE ENERGY PROJECTS


FEBRUARY 29, 2012

Homeland Security

TYPES / LOCATIONS

- HYDROKINETICS
  - WHERE THE WAVES / CURRENTS / TIDES ARE
  - NEAR SHORE / RIVERS
  - WEST COAST / MISSISSIPPI RIVER / ME / FL
- WIND
  - WHERE THE WIND IS
  - OFFSHORE
  - EAST COAST AND GREAT LAKES

Homeland Security

EXAMPLES





Homeland Security

AUTHORITY-RESPONSIBILITY

- PORTS AND WATERWAYS SAFETY ACT (PWSA)*
- Navigation, vessel safety, protection of the marine environment are matters of national importance
- Navigable waters of the United States

* P.L. 95-474; 33 U.S.C. 1223

Homeland Security

COAST GUARD'S ROLE

- Cooperating agency for NEPA purposes with the Lead Permitting Agency (LPA) such BOEM, FERC, USACE
  - ✓Develop recommendations (project specific) to provide for safety of navigation
  - ✓Develop routing measures, Limited Access Areas (safety zones, security zones) and/or Regulated Navigation Areas (RNAs) as appropriate
  - ✓Minimize potential impacts on other CG missions (SAR, MEP, Security)
  - ✓PATON if necessary
- WILL NOT APPROVE/DISAPPROVE PROJECT OR ISSUE PERMIT

Homeland Security

CRITERIA

- Site Location
  - Traffic Survey
    - Types
    - Uses
  - Navigation Safety Risk Assessment
    - Within the site
    - Proximity
- Structure
  - Risk of collision
  - Clearances
  - Impact on SAR
  - Impact on MEP
  - Security

Homeland Security

CRITERIA

- Navigation and Collision Avoidance
  - Tides and Currents
  - Weather
  - Depths
  - Visual Navigation
  - Communications
  - Radar
  - Marking
- Mitigation Measures
  - Charting / Marine Information
  - Routing Measures
  - Exclusion Zones
  - Monitoring
  - Shutdown Procedures

Homeland Security

SITING SUITABILITY CRITERIA

Is Navigational Risk Acceptable

- Δ Vessel Density → increase in encounters
- Δ Risk Due to Mixing Vessel Types
- Δ Risk Due to Allisions (fixed objects)
- Traffic Pattern Changes
- Routing Measures- Size, type, etc
- Is Economic Impact justifiable
  - Rerouting of traffic- (time and distance=$)
  - Impacts to navigation stds & watchstanding

Homeland Security

3rd DIMENSION

- Under keel clearance
- Towing catenary
- Anchoring
- Fishing
- Recreational boaters

Homeland Security

QUESTIONS

"We Help Mariners Get There"

George Detweiler
George.H.Detweiler@uscg.mil
202-372-1566 (office)
202-372-1991 (fax)

COMMANDANT (CG-5533)
ATTN: NAVIGATION STANDARDS DIVISION
US COAST GUARD
2100 2ND ST SW STOP 7580
WASHINGTON, DC 20593-7580

Homeland Security

Risk Analysis of the Potential Ecological Impacts of MHK Arrays

M. Grippo
Environmental Science Division
Argonne National Laboratory

MHK Market Acceleration

The overall goal of Market Acceleration activities is to quantify and strategically reduce the time and costs associated with siting and deploying MHK projects

MHK 2.1 Environmental Impacts and Siting

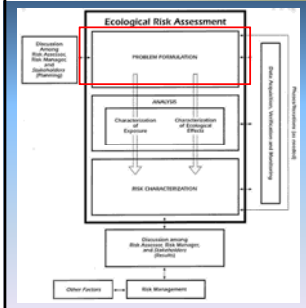
- focused on evaluating and minimizing key environmental risks to permitting and deployment
- Field and laboratory studies of turbine effects on flow, water circulation, and sediment transport
- Field and laboratory studies of noise, EMF, blade strike

MHK Market Acceleration

Argonne's role:

- Incorporate the results of field and laboratory studies conducted by partner labs into our risk analysis
- Suggest new endpoints for other labs to evaluate experimentally
- Identify the highest risk impacts that will likely require mitigation
- Identify data gaps that need to be investigated to reduce uncertainty

Aid developers in meeting NEPA requirements by addressing concerns of regulatory and management agencies



Source:Guidelines for Ecological Risk Assessment (EPA, 1998)

EPA RISK ASSESSMENT
Problem Formulation

-Conceptual models (CM):
-Diagrammatic representation of receptor and stressor linkages

-Identifies potential risks

-Excellent communications tool

Conceptual Model Development

- Review of existing literature on MHK effects
- Review by managers
- LITTLE DATA SO MUCH OF THE CM IS SPECULATIVE

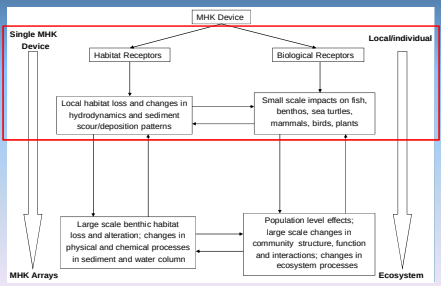
MHK development must consider:

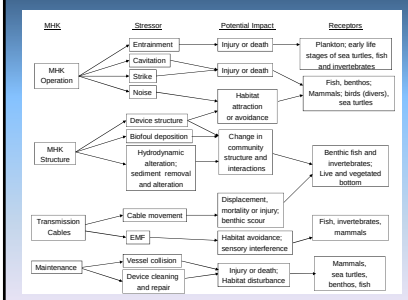
- The incremental increases in impacts from a single MHK device to large-scale commercial developments
- Interaction of the MHK device with existing impacts from other anthropogenic stressors

MHK development must consider:

- **The incremental increases in impacts from a single MHK device to large-scale commercial developments**
- Interaction of the MHK device with existing impacts from other anthropogenic stressors

Single MHK Vs. MHK Array Deployments

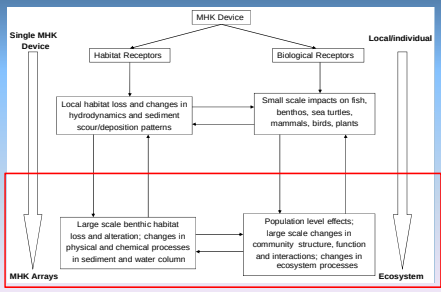


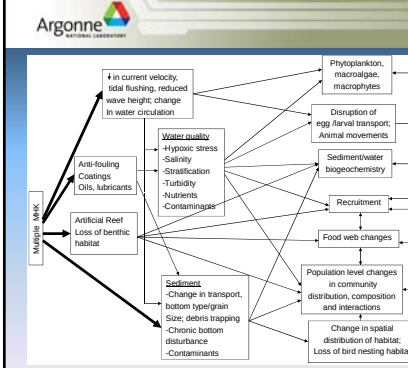


Potential effects of a single MHK device

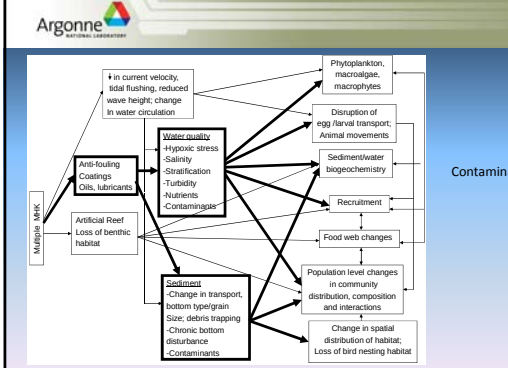
Increase in magnitude MHK arrays

Single MHK Vs. MHK Array Deployments

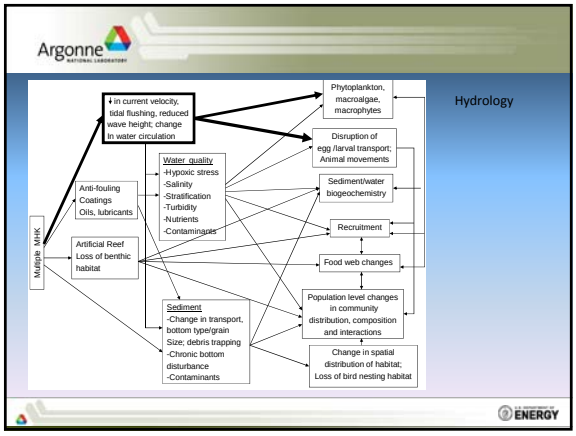


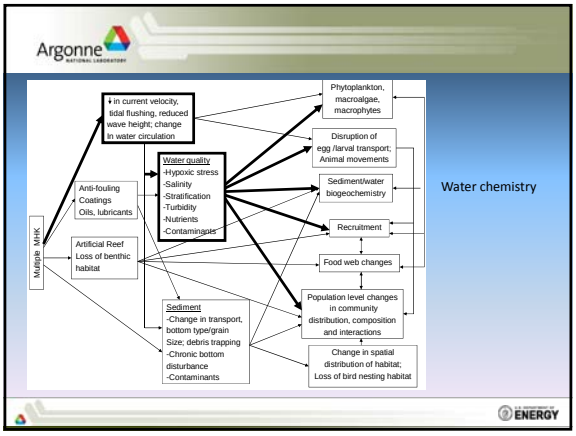


Habitat mediated impact routes from MHK arrays



Contaminants


Argonne
Hydrology
Multiple MHK
↓in current velocity, tidal flushing, reduced wave height; change in water circulation
Anti-fouling Coatings Oils, lubricants
Artificial Reef Loss of benthic habitat
Water quality -Hypoxic stress -Salinity -Stratification -Turbidity -Nutrients -Contaminants
Sediment -Change in transport, bottom type/grain Size; debris trapping -Chronic bottom disturbance -Contaminants
Phytoplankton, macroalgae, macrophytes
Disruption of egg /larval transport; Animal movements
Sediment/water biogeochemistry
Recruitment
Food web changes
Population level changes in community distribution, composition and interactions
Change in spatial distribution of habitat; Loss of bird nesting habitat
ENERGY


Argonne
Water chemistry
Multiple MHK
↓in current velocity, tidal flushing, reduced wave height; change in water circulation
Anti-fouling Coatings Oils, lubricants
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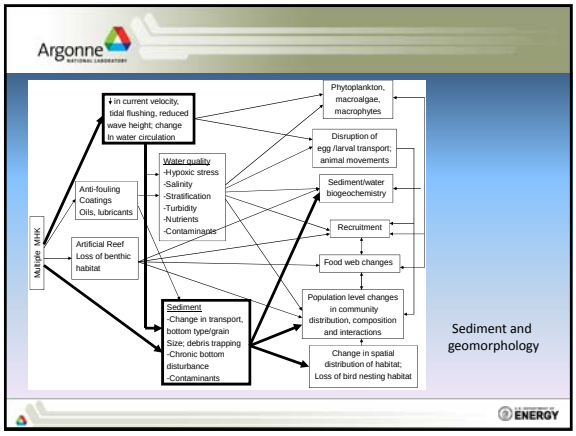
Argonne
Sediment and geomorphology
Multiple MHK
↓in current velocity, tidal flushing, reduced wave height; change in water circulation
Anti-fouling Coatings Oils, lubricants
Artificial Reef Loss of benthic habitat
Water quality -Hypoxic stress -Salinity -Stratification -Turbidity -Nutrients -Contaminants
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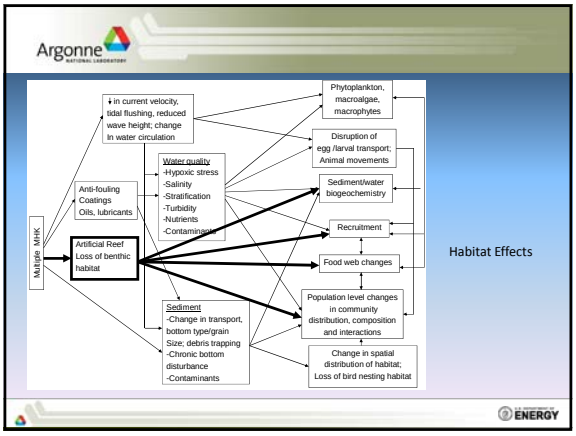
Argonne
Habitat Effects
Multiple MHK
↓in current velocity, tidal flushing, reduced wave height; change in water circulation
Anti-fouling Coatings Oils, lubricants
Artificial Reef Loss of benthic habitat
Water quality -Hypoxic stress -Salinity -Stratification -Turbidity -Nutrients -Contaminants
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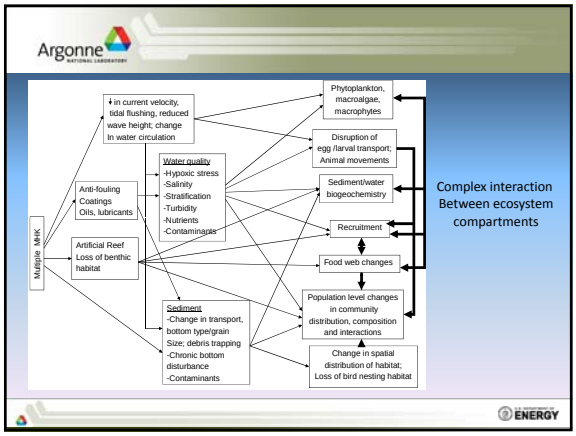
ENERGY


Argonne
Complex interaction Between ecosystem compartments
Multiple MHK
↓in current velocity, tidal flushing, reduced wave height; change in water circulation
Anti-fouling Coatings Oils, lubricants
Artificial Reef Loss of benthic habitat
Water quality -Hypoxic stress -Salinity -Stratification -Turbidity -Nutrients -Contaminants
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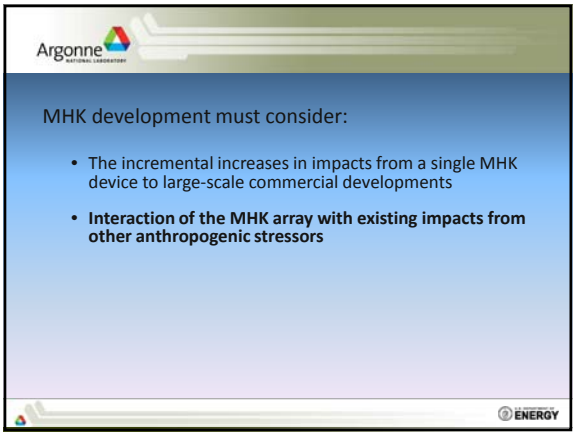
Argonne
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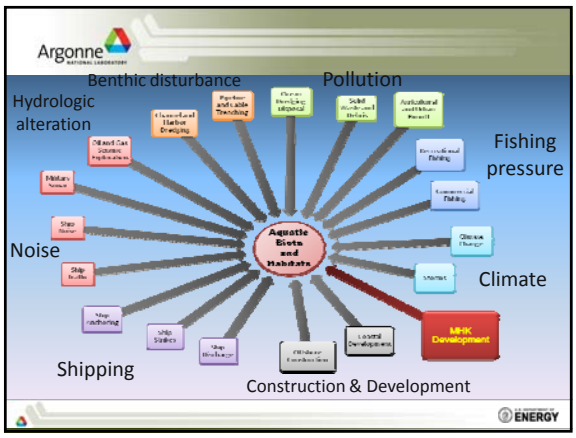
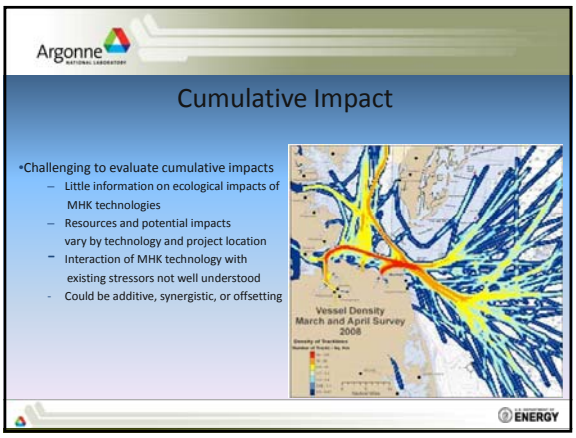
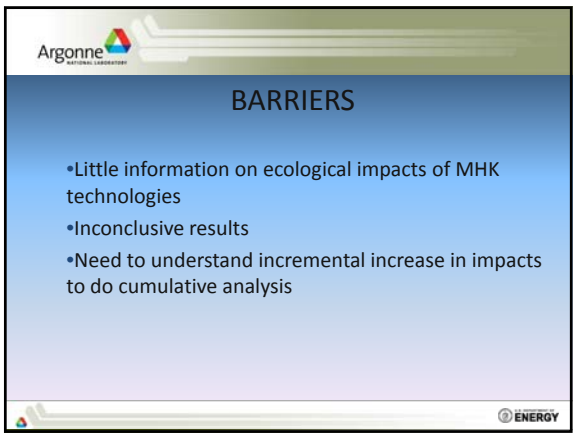
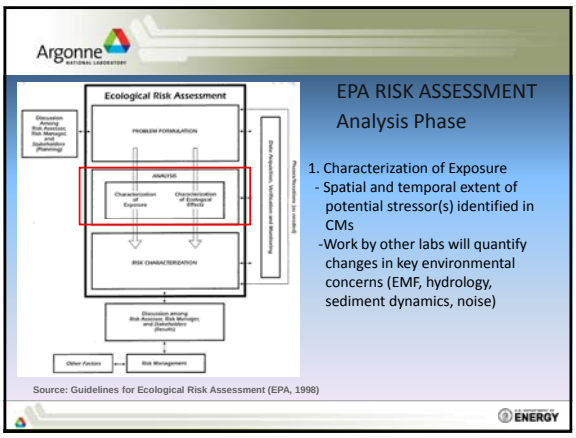
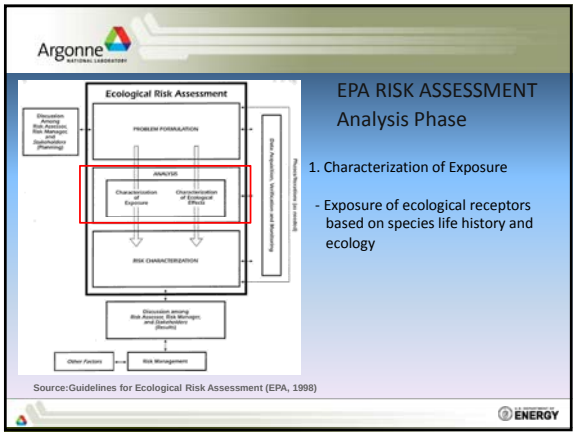
• Interaction of the MHK array with existing impacts from other anthropogenic stressors
ENERGY

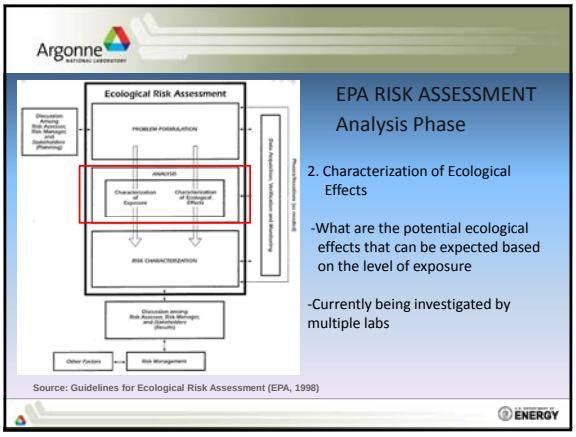

Argonne
Benthic disturbance
Pollution
Hydrologic alteration
Fishing pressure
Noise
Climate
Shipping
Construction & Development
Aquatic Biota and Habitats
MHK Development
ENERGY


Argonne
Cumulative Impact
•Challenging to evaluate cumulative impacts
– Little information on ecological impacts of MHK technologies
– Resources and potential impacts vary by technology and project location
– Interaction of MHK technology with existing stressors not well understood
- Could be additive, synergistic, or offsetting
Vessel Density March and April Survey 2008
ENERGY


Argonne
BARRIERS
•Little information on ecological impacts of MHK technologies
•Inconclusive results
•Need to understand incremental increase in impacts to do cumulative analysis
ENERGY


Argonne
Ecological Risk Assessment
EPA RISK ASSESSMENT
Analysis Phase
1. Characterization of Exposure
- Spatial and temporal extent of potential stressor(s) identified in CMs
-Work by other labs will quantify changes in key environmental concerns (EMF, hydrology, sediment dynamics, noise)
Source: Guidelines for Ecological Risk Assessment (EPA, 1998)
ENERGY


Argonne
Ecological Risk Assessment
EPA RISK ASSESSMENT
Analysis Phase
1. Characterization of Exposure
- Exposure of ecological receptors based on species life history and ecology
Source:Guidelines for Ecological Risk Assessment (EPA, 1998)
ENERGY


Argonne
Ecological Risk Assessment
EPA RISK ASSESSMENT
Analysis Phase
2. Characterization of Ecological Effects
-What are the potential ecological effects that can be expected based on the level of exposure
-Currently being investigated by multiple labs
Source: Guidelines for Ecological Risk Assessment (EPA, 1998)
ENERGY

Modeling Interactions with the MHK Device

Argonne focus:
Determine exposure to potential risks associated with proximity to device
- blade strike
- Noise

Determine behavioral effects- disruption of migratory behavior, increased energetic costs associated with movement, and the artificial reef effect

Both are critical to understanding risk.

Models- empirical and mechanistic

Empirical Models

Dogfish during night with cable off

Dogfish during night with cable on

Kernel probability density function (KPDF) uses animal movement data to statistically generate probability estimates of fish density in a given location

KPDF shading shows the probability density surfaces for 95% (dark grey), 75% (mid grey) and 50% (white).

Source: Gill, A.B., Huang, Y., Gloyne-Philips, I., Metcalfe, J., Quayle, V., Spencer, J. & Wearmouth, V. (2009).

Limitations of Empirical models

•Simply observational and does not allow a mechanistic understanding of why fish behave the way they do in response to the turbine.

•Inadequate for predicting changes in risk (i.e. exposure and behavioral effects) associated with different device designs, locations, and spatial configurations of device arrays.

Mechanistic Models

Individual Based Models (IBM)

Models animal movements based on various decision rules about how individual organisms respond to changing environmental variables.

Complex IBMs are highly data intensive and require more information on ecological processes than is typically available for an MHK development site.

Cost to collect the necessary data is likely to be prohibitive.

Mechanistic Models

Numerical Fish Surrogate (NFS) (Goodwin et al. 2006)

•Integrates fish behavioral responses with computational fluid dynamics (CFD) modeling to forecast fish movement trajectories.

•Quantify the exposure of fish to MHK devices and to determine how/if they affect fish behavior (stressor effects).

•The NFS has been used to test hypotheses about fish movements in response to dam operations and to predict fish trajectories through alternative fish bypass designs.

Mechanistic Models

The model consists of three components:

1. Computational fluid dynamics model the describes flow upstream and downstream of the device
2. Particle tracking model that simulates the movements of individual fish
3. Fish behavior model that codes for fish behavioral responses to the changing flow field. The behavior model code is based on established biological models of fish movement in response to hydrodynamic cues.

Mechanistic Models

Numerical Fish Surrogate (NFS) (Goodwin et al. 2006)

-Final product would be a 'plug and play' visual simulation model

-Forecast fish movement trajectories in response to MHK devices, allowing the prediction and minimization of risk.

Acknowledgements

US Department of Energy

Sandia National Lab

Pacific Northwest National Lab

Oak Ridge National Lab

Questions

USGS science for a changing world

Present and Future USGS Research: Effects of Hydrokinetic Turbines on Fish Behavior, Injury, and Mortality

Alex Haro

S.O. Conte Anadromous Fish Research Laboratory (CAFRL)
U. S. Geological Survey
Turners Falls, Massachusetts, USA

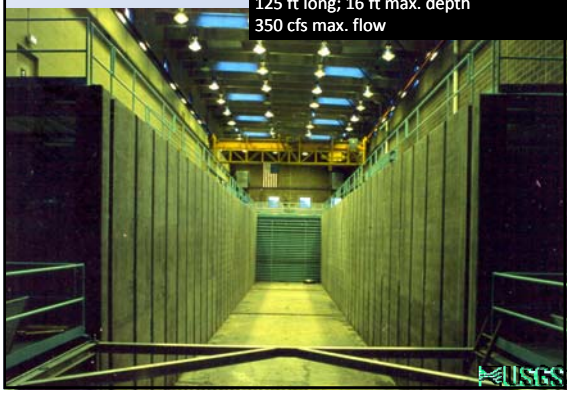
Ongoing Research and Development of Hydrokinetic Turbines: Evaluating Data Gaps Relevant to USACoE
U.S. Army Engineer Research and Development Center, Vicksburg, Mississippi
Coastal and Hydraulics Laboratory
Main Conference Auditorium

29 February & 1 March 2012

S. O. Conte Anadromous Fish Research Laboratory
Connecticut River, Turners Falls, Massachusetts

CAFRL Flume Complex

3 flumes: two 10 ft wide, one 20 ft wide
125 ft long; 16 ft max. depth
350 cfs max. flow



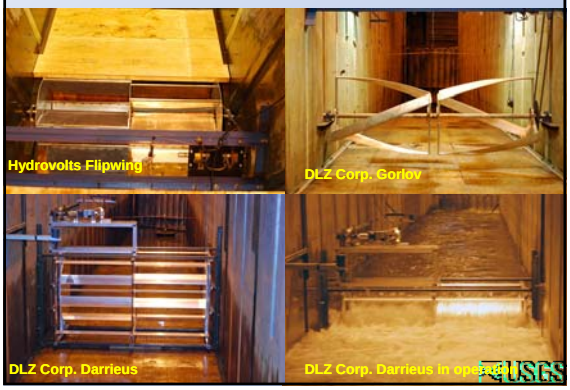
Upstream passage projects (plus some downstream ones)

Species we work with

HKT Testing:

- Hydraulic and mechanical testing
- Biological testing:
  - Evaluate major impacts of HKTs on fish: mortality, injury
  - Indirect impacts: delay, avoidance, effects on behavior
  - Responses of upstream and downstream migrants
  - Identify features of HKT design/siting that reduce negative impacts

Some HKTs mechanically/hydraulically tested at the Conte Lab

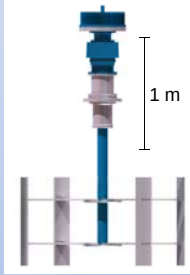


New Energy Corporation Encurrent EN-005-R5 Hydroturbine

CAFRL research funded by U.S. Department of Energy & New Energy Corp.

Partners:

- Electric Power Research Institute
- Alden Research Lab



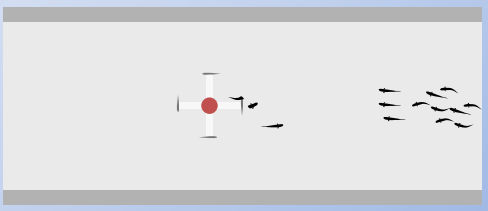
- Vertical axis Darrieus type
- 5 kW max. output
- 74 rpm @ 3 m·s^{-1} water velocity
- Small-scale deployments at remote sites

Encurrent EN-005-R5 HKT

- 2010 tests of fish avoidance & mortality
- Test species: Atlantic salmon smolts (downstream); adult American shad (upstream)

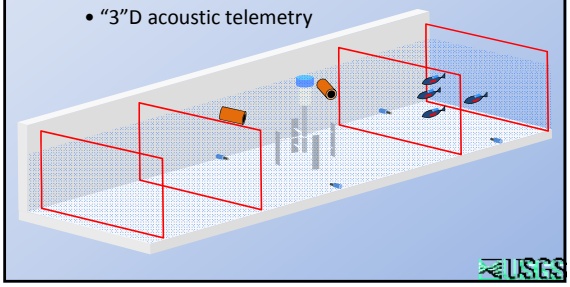
Analysis of effects:

- strike/mortality
- avoidance
- delay/barrier
- disruption of schooling

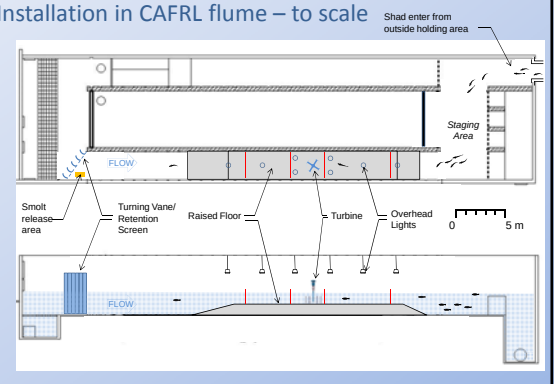


Direct measurement of strike, mortality & behavior/avoidance:

- underwater video
- PIT telemetry
- "3"D acoustic telemetry

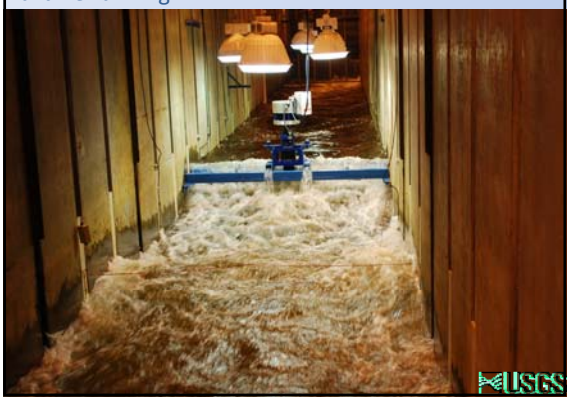


Installation in CAFRL flume – to scale

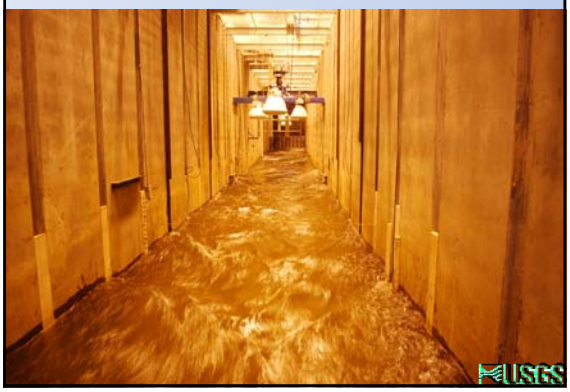


Flow/turbine startup

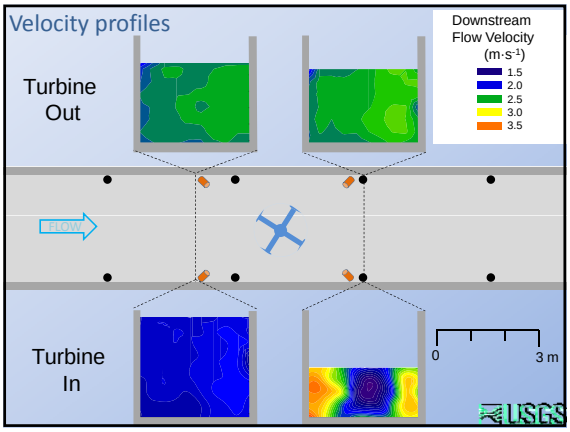
Turbine running



Turbine out – control condition



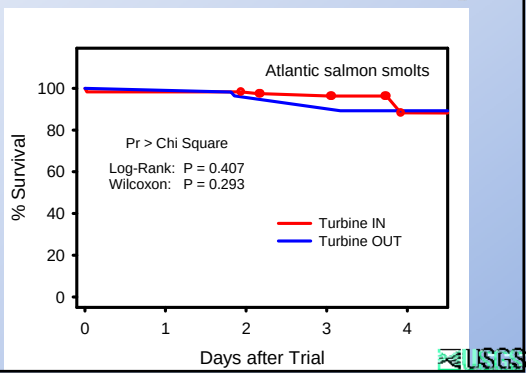
Velocity profiles



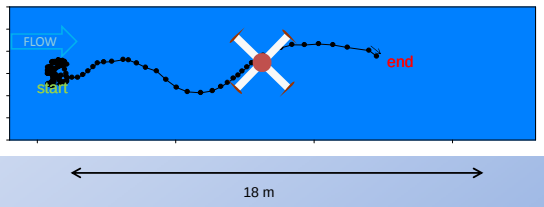
Results—Salmon smolts (downstream)

- Mean fork length: 210 mm
- Sample size:
  - Turbine In: 117
  - Turbine Out: 56
- Survival:
  - Immediate: 100% for both treatment and control groups
  - Delayed: NS between groups
- External Injuries: none detected

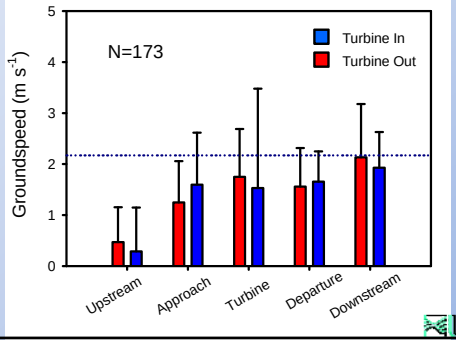
Survival: smolts



2D track of downstream smolt movement



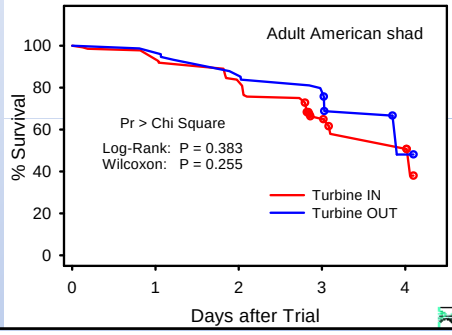
Groundspeed: smolts



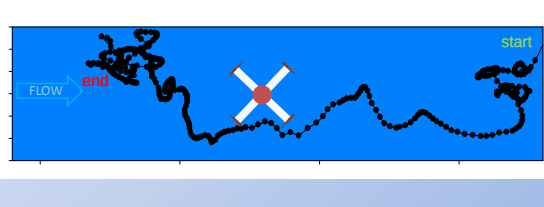
Results: adult American shad

- Mean fork length: 345 mm
- Sample size:
  - Turbine In: 115
  - Tutbine Out: 84
- Survival:
  - Immediate: 100% for both treatment and control groups
  - Delayed: NS between groups
- External Injuries: none detected

Survival: shad



2D track of upstream shad movement

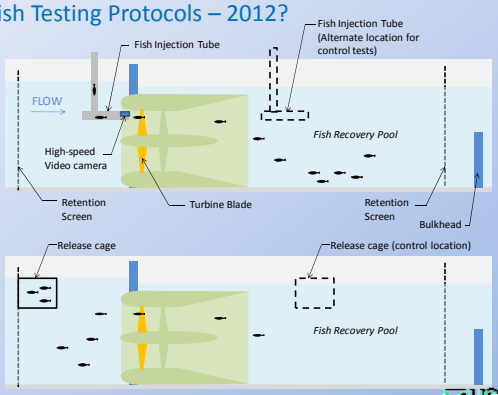


Free Flow Power Corporation Hydrokinetic Turbine

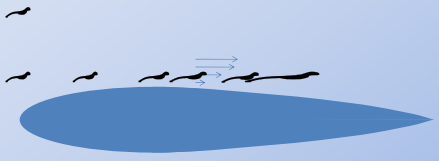
- Horizontal axis propeller type
- 15 kW max. output
- 60 rpm @ 2 m · s^{-1} water velocity
- Large open river or tidal sites

Installation in CAFRL flume – barely!

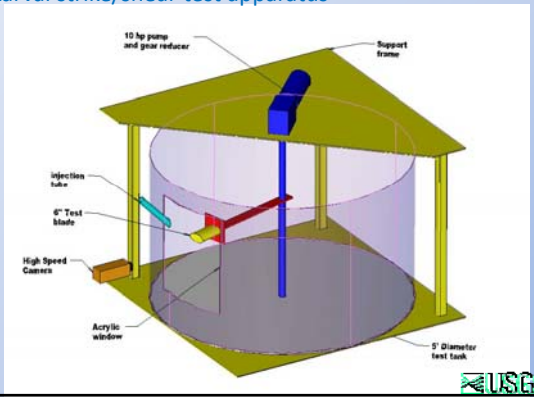
Fish Testing Protocols – 2012?



Effects on Larvae?



Larval strike/shear test apparatus



Challenges of future HKT designs

- Big vs. small
- Fast vs. slow
- Lab vs. field evaluations
- Identification and quantification of effects

CAFRL & USGS Role in HKT Research

- Ability to conduct lab testing at full scale, realistic velocities & flows, with live fish
- Comparative tests with multiple designs & conditions
- Individual tracking & quantification of fish responses, in relation to hydraulics
- Integration of results with numeric models; cumulative effects
- Guidance for HKT design/modification, siting, appropriateness for specific environments

USGS

Macrohabitat Associations of Pallid Sturgeon in the Lower Mississippi River: Application to Hydrokinetic Development.

Paul Hartfield, USFWS, Jackson, MS
Dr. Harold L. Schramm, USGS, MCRU, Mississippi State University, MS
Nathan M. Kuntz, Mississippi State University, MS

Introduction

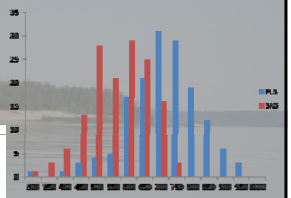
- USFWS has multiple information needs and potential concerns over effects of hydrokinetics to fish and wildlife resources:
  - Composition and abundance of fish assemblages in the project area
  - Distribution, movement, habitat use, and behavior of fish species of concern
  - Turbine entrainment of fish, invertebrates, and zooplankton
  - Electromagnetic effects
  - Acoustical effects
  - Geomorphic effects

Range of Pallid Sturgeon

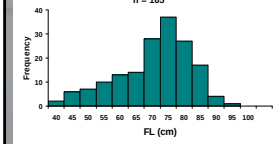
Pallid Sturgeon at ORCC

Listed as Endangered 1990

LMR Sturgeon
Captured by MSU/MDWFP
2008 – 2012
(N = 154 PLS & 154 SNS)



Mississippi River Pallid Sturgeon
Captured by WES-ERDC
1997-2004
n = 165



Pallid Sturgeon Habitat Use and Selection in the Lower Mississippi River

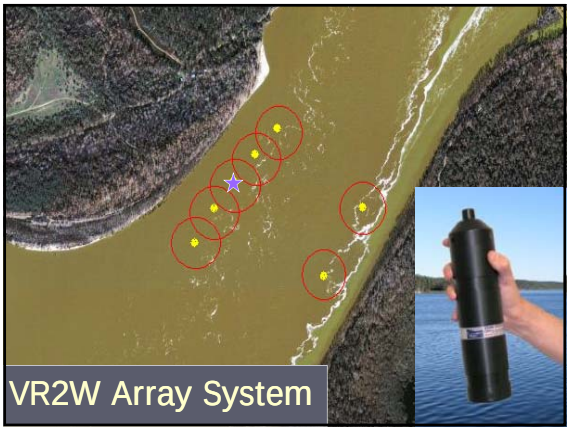
Nathan M. Kuntz[1], Jason R. Herrala[1], Harold L. Schramm, Jr.[2], and Paul Hartfield[3]

[1]Department of Wildlife, Fisheries, and Aquaculture, Mississippi State University, Mississippi State, MS 39762
[2]U.S. Geological Survey, Mississippi Cooperative Fish and Wildlife Research Unit, Mississippi State, MS 39762
[3]U.S. Fish and Wildlife Service, Mississippi Ecological Services Field Office, 6578 Dogwood View Parkway Suite A, Jackson, MS 39213

Methods

- Captured and surgically implanted
- Actively tracked each month

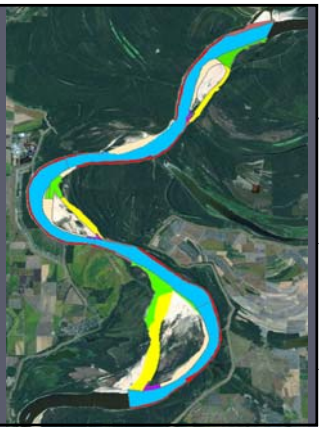
- Depth, surface current velocity
- Water temperature, river stage



Methods

Habitat Designations

- I. Main Channel
- II. Channel Border
  - A. Outside Bend
    - 1. Revetted Bank
    - 2. Natural Bank
  - B. Sandbar
- III. Wing Dike
- IV. Secondary Channel
- V. Island-tip

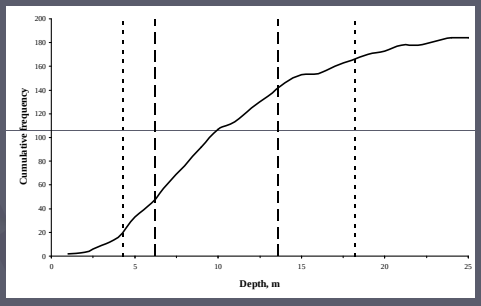


Results

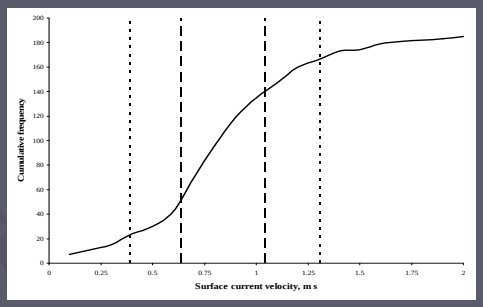
- 74 pallid sturgeon tagged
- 35 individual fish for 165 detection
- 27 fish located between 2 and 14 times

	Island tip	Natural bank	Sandbar	Wing Dike	Secondary channel	Revetted bank	Main channel
Number of detections (%)	22 (13)	18 (11)	28 (17)	27 (17)	22 (13)	18 (11)	30 (18)
Percent of total area	1.2	2.2	10.8	8.6	12.8	9.4	55
D	+++	+++	+	+	-	-	---

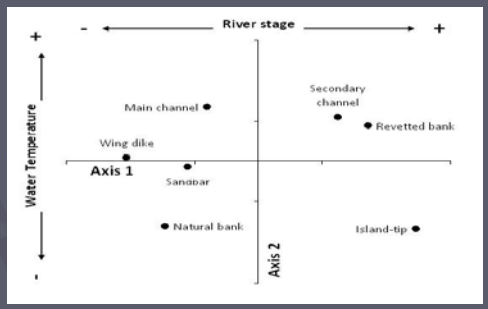
Depth



Surface Current Velocity



NMS Ordination



Discussion

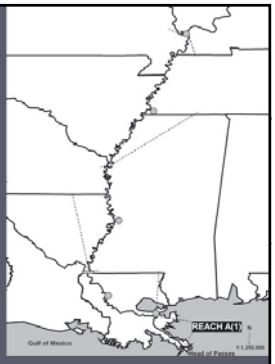
- All habitats were used but at different rates
- Habitat use varied with hydrograph
- Fish remained in a short stretch of river
- Showed affinity for a relatively narrow range in depth and current velocity
- Mobile arrays show limited PLS short term local movements

Management Reaches of the LMR

ERDC has divided LMR into 4 reaches based on geomorphology and degree of modification:

- Cairo to the mouth of Arkansas River (ARR);
- ARR to the Old River Control Structures (ORCS);
- ORCS to New Orleans;
- New Orleans to the Gulf of Mexico.

Our study site was just below the ARR.



From Killgore *et al.*, 2007

Potential Effects of Hydrokinetic Generation on Movements and Habitat Use of Endangered Pallid Sturgeon and Shovelnose Sturgeon in the Mississippi River

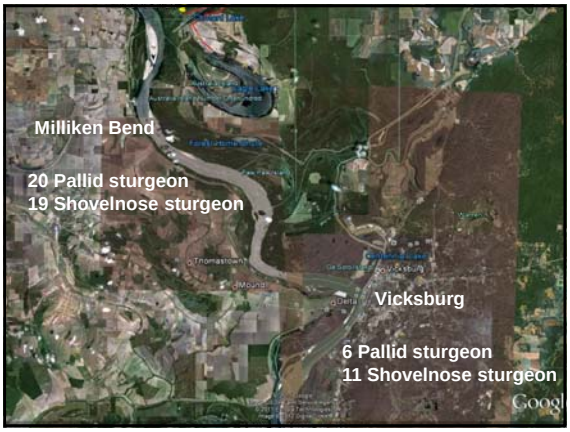
Collect and measure 20+ each Pallid and Shovelnose sturgeon at 3 proposed hydrokinetic sites and 3 control sites in the LMR

Take measurements, genetic samples, and habitat data; implant 5-year sonic tags into all large sturgeon

Monitor sturgeon locations and habitat associations for 2 to 3 years

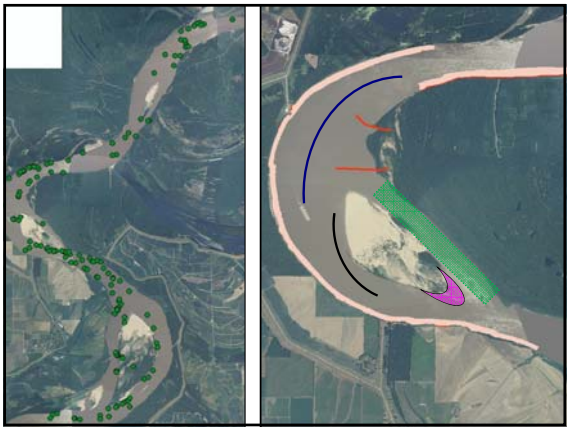
Hydrokinetic Study Sites
Identified by FFP

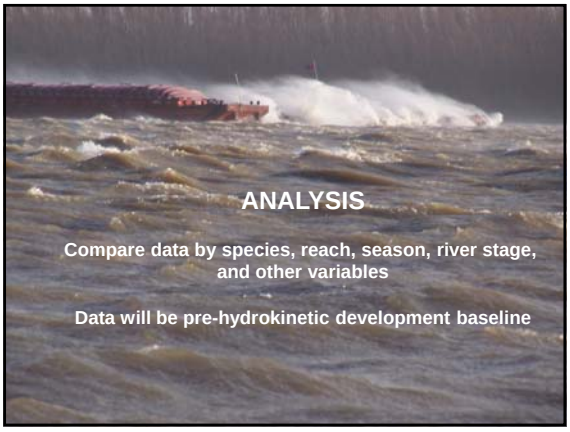
- Tunica (Mhoon Bend), MS/AR
  - Catfish Point, MS/AR
- Vicksburg, MS/LA
  - Milliken Bend, Willow Cutoff, MS/LA
- Baton Rouge, LA
  - Profit Island, LA



STURGEON IMPLANTED FOR HYDROKINETIC STUDY

Locality	PLS	SNS	INT	TOTAL
Tunica, MS (RM 665 - 685)	19	20	1	40
Catfish Point, MS (RM 559 - 580)	60	2		62
Greenville, MS (RM 537 – 540)	8	0		8
Milliken Bend (RM 454 – 461)	20	19		39
Vicksburg, MS (RM 430 - 440)	6	11	2	19
Profit Island, LA RM 240 – 246)	4	3		7
Baton Rouge, MS (RM 233 – 238)	4	3	1	8
Total	121	58	4	183




ANALYSIS
Compare data by species, reach, season, river stage, and other variables
Data will be pre-hydrokinetic development baseline


Questions?

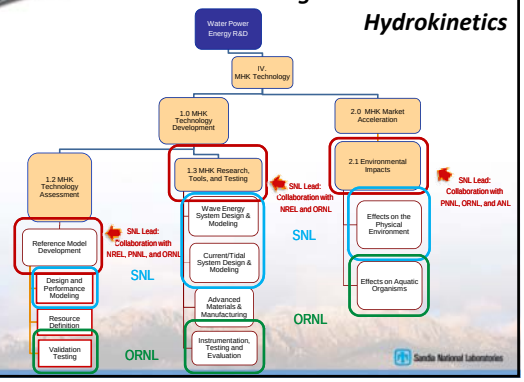
National Lab Activities in Marine Hydrokinetics: Model Development

Richard Jepsen,
February 29, 2012
KET Workshop, Vicksburg, MS

Water Power Program Mission

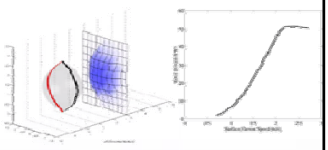
- **Research, test, and develop innovative technologies capable of generating renewable, environmentally responsible, and cost effective electricity form water resources.**
  - Marine Hydrokinetic Technologies
    - Resource
      - Wave energy has a potential resource of 400 GW
      - Tidal currents have a potential resource of 60 GW
      - Free flowing rivers have a potential resource of 60 GW
    - R&D Focus
      - Determine convertible resource potential
      - Address environmental challenges
      - Demonstrate performance viability and identify technology leaders
      - Identify key cost drivers and opportunities for cost reduction

Water Power Program Chart: Marine Hydrokinetics



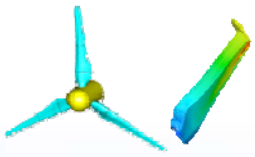
Single Turbine: Modeling Performance

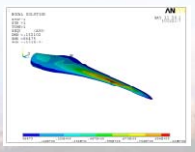
- **Single Device**
  - Development of CACTUS Code for both cross flow and axial flow turbine analysis
  - Design and test of high performance turbine blade (with Penn State ARL and UC Davis)

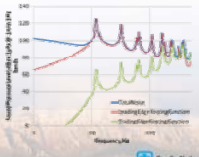


Single Turbine: Modeling Acoustics

- **Objectives**
  - Develop methodology to predict acoustic signature of MHK turbines
  - Predict acoustics from a representative turbine
- **Uses**
  - Inform acoustic dose/response studies
  - Design quieter blades

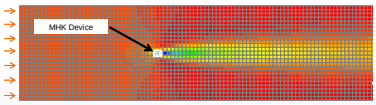






Large Scale Hydrodynamics: Current/Tidal Regimes

- **Development of 'MHK Friendly Algorithms' and incorporation with SNL-EFDC open-source code**



Treats MHK-turbine device as a momentum sink and source of turbulent kinetic energy and its dissipation rate

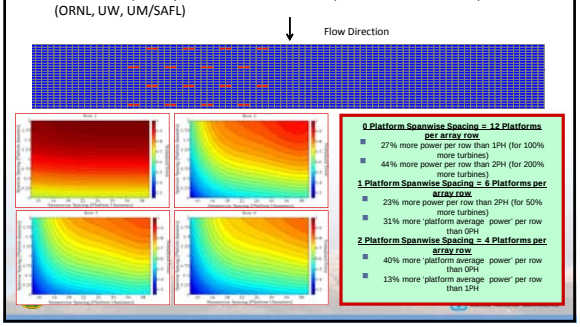
K-ε modifications

Empirical constants

$$S_K = \frac{1}{2} C_T A_{MHK} \left(\beta_p U^3 - \beta_d U K \right) \qquad S_\varepsilon = C_{\varepsilon 4} \frac{\varepsilon}{K} S_K$$

SNL-EFDC for Array Performance

- SNL-EFDC has been developed to include MHK devices as momentum/energy sinks
- The model is partially validated with more tests planned in the laboratory and field (ORNL, UW, UM/SAFL)



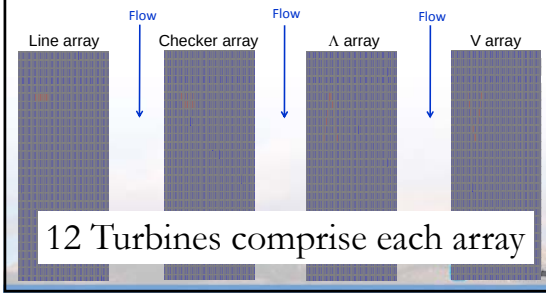
0 Platform Spanwise Spacing = 12 Platforms per array row
- 27% more power per row than 1PH (for 100% more turbines)
- 44% more power per row than 2PH (for 200% more turbines)

1 Platform Spanwise Spacing = 6 Platforms per array row
- 23% more power per row than 2PH (for 50% more turbines)
- 31% more 'platform average power' per row than 0PH

2 Platform Spanwise Spacing = 4 Platforms per array row
- 40% more 'platform average power' per row than 0PH
- 13% more 'platform average power' per row than 1PH

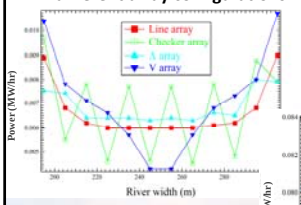
Alternate Turbine Array Configurations

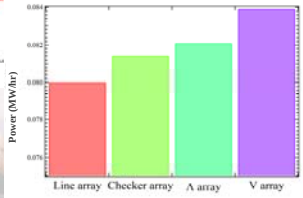
- **Optimizing for maximum energy conversion: Comparing different array configurations**



Turbine Array Comparisons

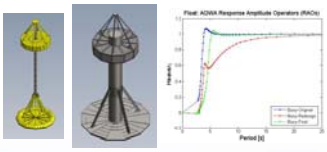
- **Optimizing for maximum energy conversion: Comparing different array configurations**



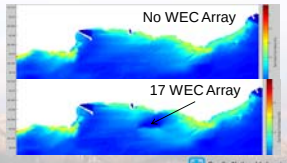


Wave Device Modeling

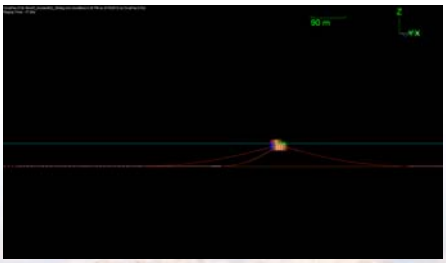
- **Single Device**
  - Integrate Fluid-Structure interactions with performance modeling including PTO



- **Device Arrays**
  - Represent devices as reflection and/or transmission sink
  - Integrated into SWAN/SNL-EFDC



Mooring and Device Modeling



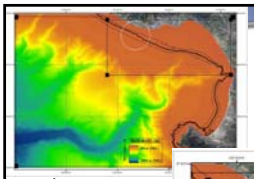
WEC Modeling for Large Scale Hydrodynamics

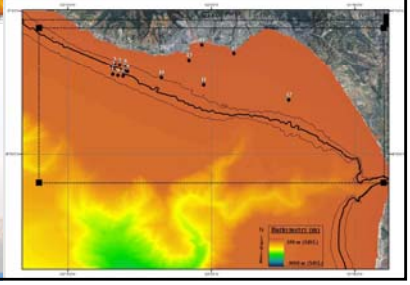
- **Implementation of WECs within wave model (SWAN), WECs represented as:**
  - discrete obstacles with constant transmission/reflection coefficients (simplest and currently employed technique)
  - 'Dam' obstacles where T/R are a function of incident waves and 'dam' height
  - Frequency filtering obstruction where energy absorption varies across the wave frequency spectrum (i.e. maximum absorption at 7-10s wave periods)

- **Wave Modeling Sensitivity Study in Montery Bay, CA**
  - Expanded on previously validated wave model of Montery Bay
  - Varied WEC coefficients and incident wave conditions (117 combinations)
  - Varied spacing of 10 WEC array (2.5X, 5X, 10X)
  - Monitored wave height, period, and direction at 15 output locations around and landward of array

Coefficient	Value(s)
Transmission	[0.00, 0.25, 0.50, 0.75, 1.00]
Reflection	[0.00, 0.25, 0.50]
Frequency Spreading (gamma)	[1.0, 3.3, 10.0]
Directional Spreading (m)	[2.0, 10.0, 25.0]

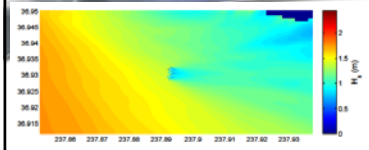
Monterey Bay Wave Model with WECs and Output Locations





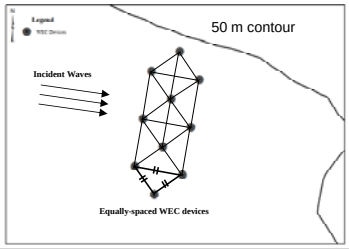
- **Results**
  - Trans. coef. Is most sensitive parameter largely effecting Hs
  - Largest effects landward of array (but not always in-line)
  - Lower FSC enables wave direction changes to penetrate further
  - Tp most affected by DSC
  - Wave direction most affected by DSC

WEC Spacing



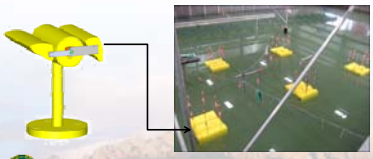
2.5X, 5X, 10X

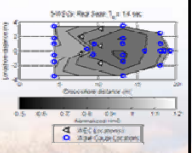
- **Effects of Array spacing**
  - More densely packed arrays have larger effects near the array
  - Less densely packed arrays have larger effects further away from array



WEC Array Data for Model Development and Validation

- In collaboration with OSU and Columbia Power, the first and only test data for WEC arrays has been generated
- In collaboration with OSU, SNL will perform WEC modeling sensitivity study within OSU Tsunami Wave Basin to gain insight into effectiveness of WEC representation techniques and ultimately for model validation

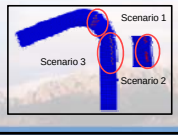


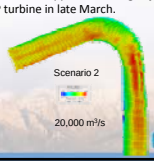


Sandia National Laboratories

Environmental Studies: Mississippi River

- **Project Objectives**
  - Investigate the potential for alterations to river height due to emplacement of an array of turbines in relation to increased risk of flooding
  - Determine changes in bottom and bank sediment stability caused by alterations to river flow through and around various arrays of turbines
- **Status**
  - Developed model of Scotlandville Bend (near Baton Rouge, LA) and working with FFP on implementing realistic array scenarios
  - Added functionality to SNL-EFDC to allow placement of turbines based on a reference plane in the water (previously turbines were placed relative to the local bed elevation)
  - Planned additional environmental measurements to support modeling objectives, to be coordinated with field campaign around FFP turbine in late March.

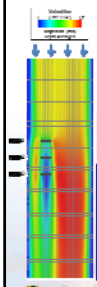


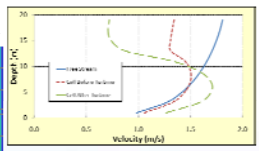


Sandia National Laboratories

Environmental Effects

- **Quantifying effects of altered flow around array**





For this array design, the river velocity increases to either side of and below the array. This altered velocity regime impact both wildlife and shipping traffic. A known effect of the velocity change is its increase on bed and bank shear stress, which could negatively impact sediment transport by increasing risk of bank erosion and inducing modification to the benthic habitat.

$V_{mhk\ bank} = 1.5 * V_{o\ bank}$
$V_{mhk\ bed} = 1.3 * V_{o\ bed}$

$\tau \sim V^2$

$\tau_{mhk\ bank} \sim 2.25 * \tau_{o\ bank}$
$\tau_{mhk\ bed} \sim 1.7 * \tau_{o\ bed}$

$ER \sim \tau^2$
$ER \sim V^4$

$ER_{mhk\ bank} \sim 5 * ER_{o\ bank}$

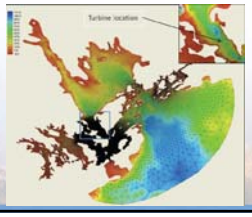
$ER_{mhk\ bed} \sim 3 * ER_{o\ bed}$

Model can inform Environmental Sampling Plans

Sandia National Laboratories

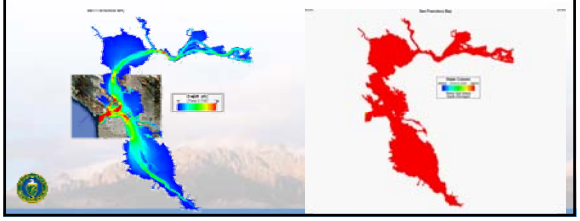
Environmental Studies: Cobscook Bay

- **Project Objectives**
  - Investigate the potential for altering the natural dispersion/migration of baby scallops
- **Status**
  - Collaborating with U. Maine professor, Dr. Huijie Xue, on model development
    - Dr. Xue has a large domain model that focuses on the Western Passage
  - Developed a **boundary extraction tool** that can extract water/land boundaries (including islands) from an image via a 'flood filled method'.



Environmental Studies: San Francisco Bay

- **Project Objectives**
  - Investigate the relationship between the amount of energy converted in the tidal throat (under and behind the Golden Gate Bridge) to the residence time/water age/ within the Bay
- **Status**
  - Base model has been developed and run with and without MHK
    - 28 day simulation of spring/neap tidal cycle, requires 6 days computation time
    - Initial results show that effects of 60, 10-m MHK-turbines has negligible affect on flushing

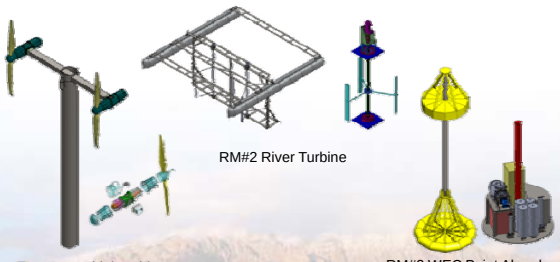


Environmental Studies: Kaneohe Bay

- **Project Objectives**
  - Assess potential changes to wave, current, and sediment transport patterns from WEC installations
- **Status**
  - Developing relationships with UH and Navy and identifying key collaborators
  - Collecting baseline data for model parameterization
    - Wave spectra, bathymetry, sediments, etc…

Reference Models

Goal: Develop a representative set of Reference Models (RM) for the MHK industry to develop baseline cost of energy (COE) and evaluate key cost component/system reduction pathways.



RM#2 River Turbine

RM#1 Tidal Turbine

RM#3 WEC Point Absorber

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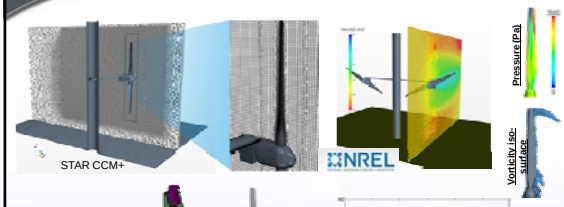
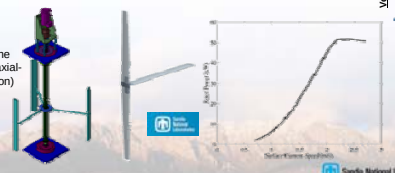
Reference Models: Application of Analysis Tools

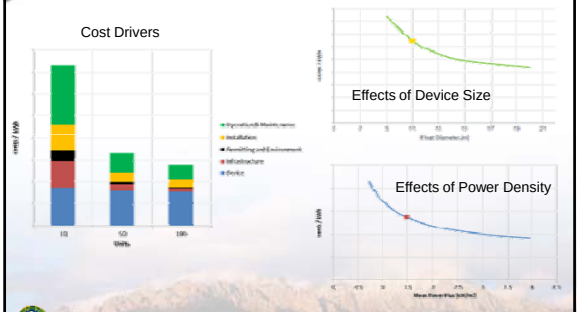


CACTUS (Code for the Analysis of Cross and axial-flow TUrbine Simulation)



Reference Model: Impact on COE

Cost Drivers



Thank You

Questions???

USACE Regulatory

- Section 10 Rivers and Harbors Act of 1899
  - Structures/work affecting the course, location, or condition of Navigable Waters
- Section 404 Clean Water Act
  - Discharges of Dredged or Fill Material into Waters of the United States
- District Commanders make permit decisions
  - ~1,300 regulators reviewing ~80,000 applications/yr
  - Regulatory vs. Civil Works boundaries

BUILDING STRONG®

USACE Regulatory

- FERC lead agency, USACE cooperating agency
  - MOU - March 11, 2011
  - Review/Comment on EIS documents
  - Participate in the development of monitoring/data collection protocol plans
- Permit Type: Individual vs. General
  - NWP #52 Water-Based Renewable Energy Pilot Projects
  - Public Interest Review
  - 404(b)(1) Guidelines
- Coordinate with USACE Navigation and Hydropower

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Challenges and Opportunities

- Competing interests
  - Corps must determine proposed project is not contrary to the public interest
  - Public interest review factors include:
    - Navigation, Safety, Recreation, Fish and Wildlife, Energy Needs, Wetlands, Historic Properties, Shore erosion and accretion, Water Supply and Conservation, and 11 others.
- Understanding potential effects and how to mitigate them
- Forums such as this to exchange information and ideas
- Proactive federal approach

BUILDING STRONG®

Hydrokinetic Energy Effects on Navigation

William H. McAnally
Northern Gulf Institute

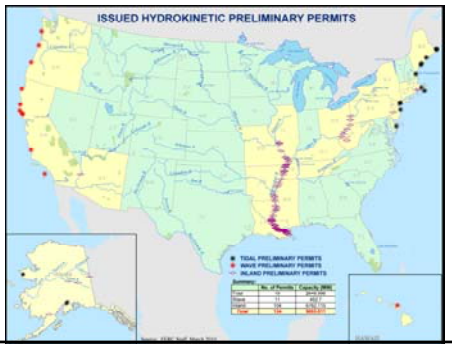
Trey E. Davis
U.S. Army Engineer Research and Development Center

Sandra L. Ortega-Achury
Civil and Environmental Engineering
Mississippi State University

US Army Corps of Engineers

NGI

FERC Permits



2

In-Stream Hydrokinetics

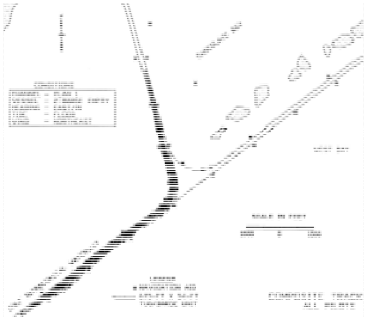
Potential effects* from hydrokinetic facility installation, supporting infrastructure, operation, or signage on:

- Visual navigation
- Electronic navigation and communications
- Search and rescue, counter pollution, or salvage operation in or around an installation
- Tides, streams and currents
- Navigation safety (likelihood of allision and collision)

* Marine and Hydrokinetic Renewable Energy Technologies: Potential Navigational Impacts and Mitigation Measures, Office of Energy Efficiency and Renewable Energy, U. S. Department of Energy, Washington, DC. 2009.

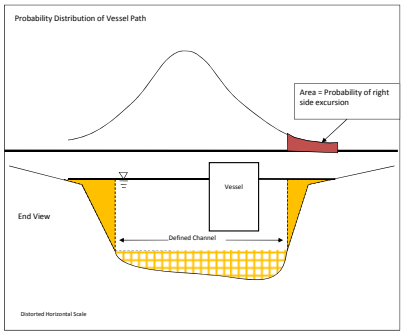
3

Simulated Vessel Passes Thru Turn



4

Probability of Vessel Excursion



5

Safety Example

- A sample* of 936 vessel accidents occurring in the Lower Mississippi River between 1979 and 1987:
  - 207 vessel-vessel collisions
  - **422 vessel-fixed structure allision**
  - **297 groundings**
  - 10 other
- 0.32 out-of-channel accidents per mile per yr

* Le Blanc, L. A. and C. T. Rucks 1996. A multiple discriminant analysis of vessel accidents, *Accident Analysis and Prevention*, 28, No. 4. 501-510.

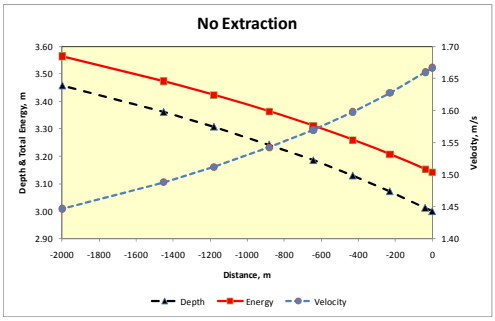
6

Physical Effects Example: Hypothetical Waterway

Variable	Value
Discharge	10,000 m^3/sec
Roughness Coefficient, *n*	0.025
Length of Channel	2,000 m
Bottom Slope	0.0001
KE Coefficient	1
Tailwater Depth	3 m
Extraction Loss Fraction	0 to 30 %

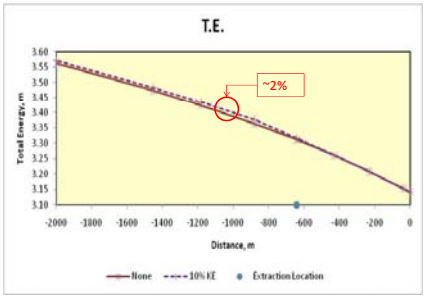
7

Hydraulic Calculations, No Extraction



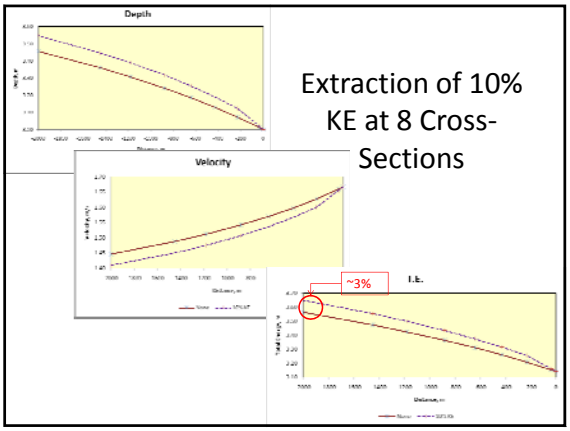
8

Extraction of 10% KE One Cross-Section

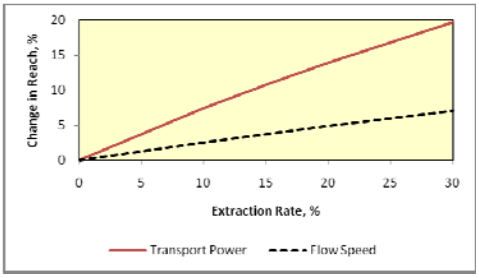


9

Extraction of 10% KE at 8 Cross-Sections



Extraction of Various KE at 8 Cross-Sections:



11

Physical Effects

Precise resolution of effects must be addressed by multi-dimensional numerical site-specific models.

Hydrokinetic generators in tidal and non-tidal rivers may cause:

- Decreased flow speeds
- Altered water levels (positive or negative changes)
- Increased sediment deposition in the vicinity
- Altered salinity intrusion (positive or negative changes) in estuaries
- Scour around the structures with downstream deposition

12

Conclusions

- Hydrokinetic power offers a significant contribution to U.S. electricity needs.
- Potential effects of hydrokinetic installations on navigation include:
  - Vessel accidents
  - Decreased flow speeds & altered water levels
  - Localized bed scour & far field sediment deposition
  - Altered salinity intrusion in estuaries
- Site conditions will dictate whether a specific site is suitable for hydrokinetic electricity generation or not.
- Multi-dimensional numerical modeling of sites is required.
- Cumulative impacts of multiple installations must be considered.

13

Contact Information

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MISSISSIPPI STATE UNIVERSITY

US Army Corps of Engineers
Engineer Research and Development Center

14

National Lab Activities in Marine Hydrokinetics: Technology Performance Testing

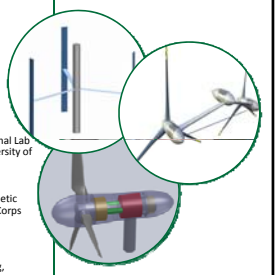
Vincent Neary
MHK Technologies Lead, Energy-Water-Ecosystem Engineering Group, Oak Ridge National Laboratory

Co-Principal Investigators:
B Gunawan, M Bevelhimer, G Cada, P Schweizer Oak Ridge National Lab
C Hill & LP Chamorro, F Sotiropoulos, St. Anthony Falls Lab, University of Minnesota

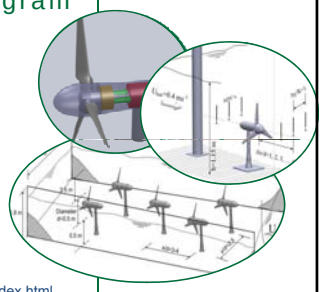
KET Workshop: Ongoing Research and Development of Hydrokinetic Turbines: Evaluating Data Gaps Relevant to United States Army Corps of Engineers

29 February 2012

U.S. Army Engineer Research and Development Center, Vicksburg, Mississippi, Coastal and Hydraulics Laboratory, Main Conference Auditorium



DoE Marine and Hydrokinetics Program Goals

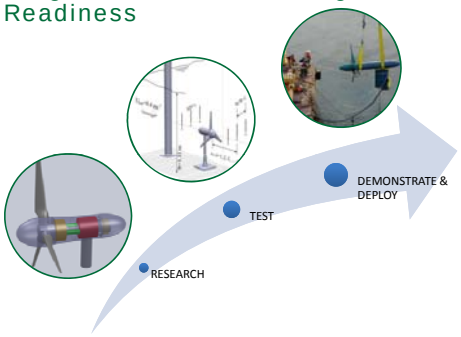


http://www1.eere.energy.gov/water/index.html

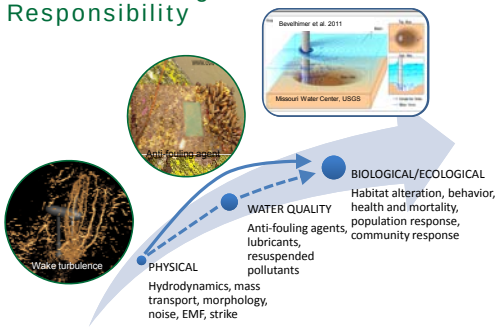
DoE Marine and Hydrokinetics Program Goals: Assessing Resource Potential

- Theoretical Resource
  - Wave 400 GW
  - Current
    - River 60GW
    - Tidal 60GW
    - Ocean TBD
- Technical Resource
  - TBD
- Practical Resource
  - TBD

DoE Marine and Hydrokinetics Program Goals: Advancing Technology Readiness

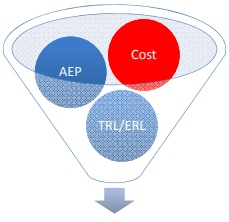


DoE Marine and Hydrokinetics Program Goals: Ensuring Environmental Responsibility



DoE Marine and Hydrokinetics Program Goals: Reducing the Cost of Energy (COE)

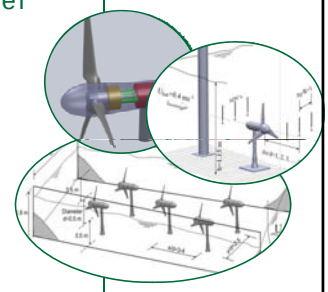
$$COE = \frac{Cost}{AEP}$$



Cost=f(manufacturing, O&M, environmental mitigation, monitoring, permitting…)

Annual Energy Production (AEP)=f(current frequency, duration, magnitude)

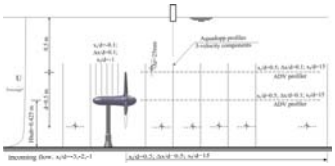
Laboratory Testing: SAFL Main Channel



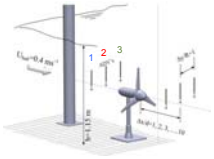
Study objectives

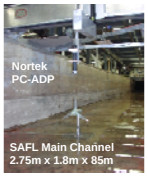
- Validation data sets
  - Technology CFD design models: Performance curves
  - Near- and far-field CFD hydrodynamic models: Inflow and wake characteristics
- TRL and ERL assessment
- COE assessment
- Best practices for lab and field testing

Experimental Set-up

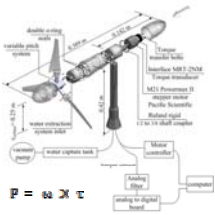


- SAFL Main Channel
- Width = 2.75m
- Flow depth = 1.15m
- H_{hub}=0.425m
- U_{bulk}=0.4 m/s
- Tip speed ratio λ=1.9 to 8.8
- Froude number similarity





Measured performance curve

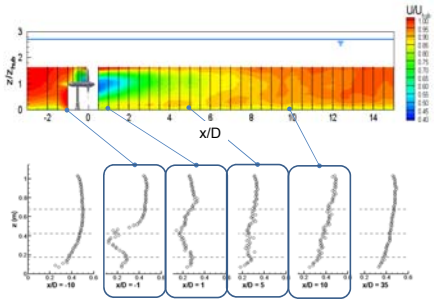


$P = \omega \times \tau$

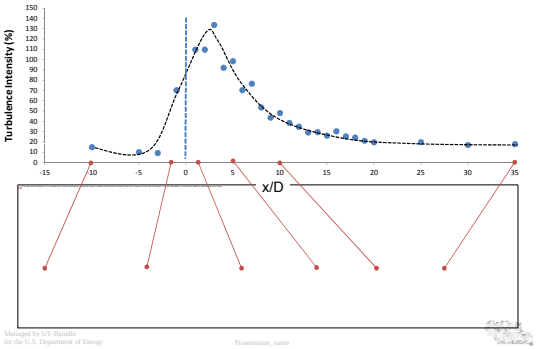
$C_p = \frac{P}{\rho A U^3}$

RPM	Tip Speed Ratio	Mean Torque	C_p
30	1.9	0.1601	0.0743
45	2.9	0.3010	0.2096
60	3.9	0.3836	0.3562
75	4.9	0.4015	0.4660
85	5.6	0.3523	0.4634
90	5.9	0.3456	0.4813
105	6.9	0.2442	0.3968
120	7.8	0.1120	0.2080
135	8.8	-0.0260	-0.0544

Inflow and wake measurements: vertical mean longitudinal velocity

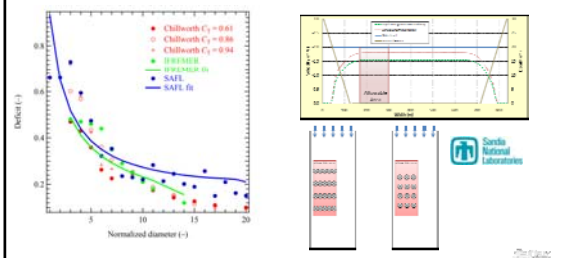


Inflow and wake measurements: turbulence intensity



Inflow and wake measurements: SNL-EFDC Verification and Validation

- **Verification and validation of SNL-EFDC, open-source code for optimizing machine array spacing**



Future work: Reference turbine testing

- Validation data sets
- TRL and ERL assessment
- COE assessment
- Best practices for lab and field testing

Full scale field testing: Scotlandville Bend, Mississippi River

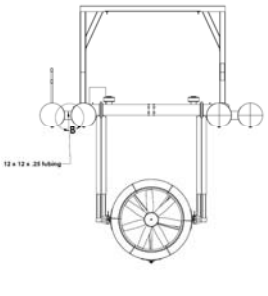
FREE FLOW POWER

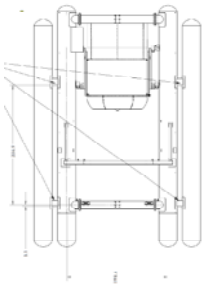
Sandia National Laboratories · OAK RIDGE National Laboratory · NREL

UNIVERSITY of WASHINGTON · St. Anthony Falls Laboratory

U.S. DEPARTMENT OF ENERGY · OAK RIDGE NATIONAL LABORATORY

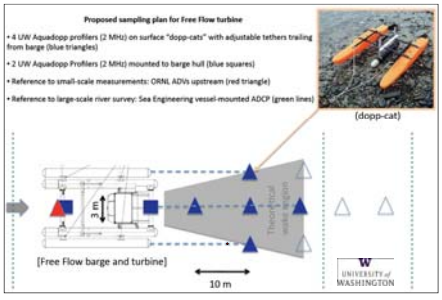
Test platform





Test Plan

- Simultaneous measurements inflow, wake flow, noise, EMF, power, etc..
- Data will be public; first of it's kind for MHK-turbine



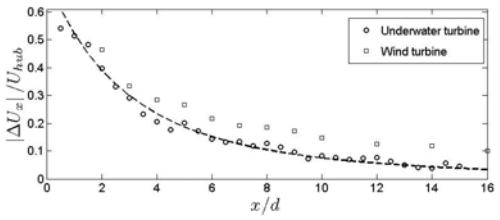
Data Gaps (Most pressing data needs, DoE)

MHK resource	Technology readiness	Environmental readiness	Cost of energy drivers
• Machine specs, performance curves, spacing • Siting constraints	• Survivability in harsh environment • Wake effects on machine spacing	• Fish-machine interaction • Physical impacts of wakes • EMF • Noise	• Spacing • Maintenance costs • Permitting and monitoring

Partners

Energy Efficiency & Renewable Energy
VERDANT POWER
Sandia National Laboratories
NREL
FREE FLOW POWER
Argonne
Pacific Northwest
UNIVERSITY of WASHINGTON

Inflow and wake measurements: velocity deficit



Kinetic Energy Turbine Workshop
February 29 – March 1, 2012
Coastal & Hydraulics Lab
Vicksburg MS

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Engineer Research and Development Center (ERDC)

Corps Mission Areas

- Navigation
- Flood Risk Management & Coastal Storm Reduction
- Ecosystem Restoration
- Watershed Planning
- Hydropower
- Water supply
- Recreation
- Emergency Operations





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Impetus

"Corps is responsible for Federal navigation channels and structures…"

The Corps needs to understand the potential impacts of KET to navigation

How do we address KET impacts?

Navigation study – Physical Models; Numerical Models

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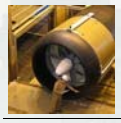
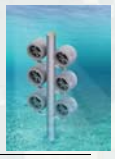
Kinetic Energy Turbine Workshop

•Present ongoing research/planning activities by USACE and Federal agencies

•Identify potential regulatory and permitting needs that require USACE action

•Develop a list of research and development needs to address unresolved navigation, flood risk management and environmental issues





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Introduce yourselves

Name & affiliation?

From originally & live now?

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Contact Information

Richard Styles
richard.styles@usace.army.mil

Coastal & Hydraulics Lab
3909 Halls Ferry Rd
Vicksburg MS 39180

Online:

- CHL website: http://chl.erdc.usace.army.mil/navigationbranch
- Navigation Wiki …
- http://cirp.usace.army.mil/navwiki/index.php/Main_Page

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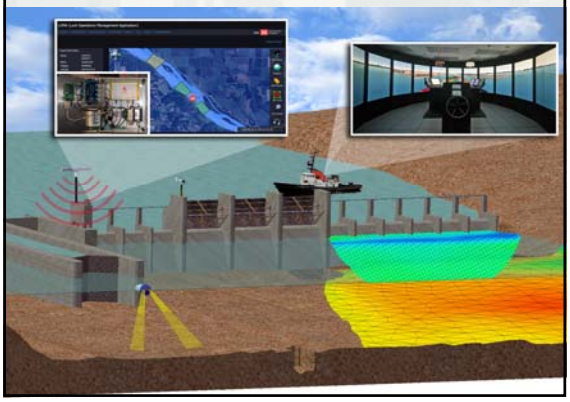


Ongoing Research and Development of Hydrokinetic Turbines

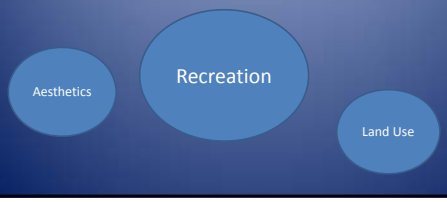
Hosted by USACE
February 29, 2012
Vicksburg, MS

A National Park Service (NPS) Perspective

Randy Thoreson - Hydro Group
randy_thoreson@nps.gov
651-293-8450

NPS Hydro Review Authority

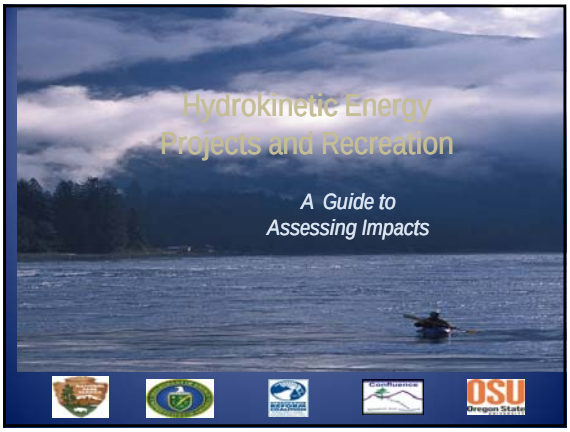
* Federal Power Act
* Wild and Scenic Rivers Act 1968
* Outdoor Recreation Act of 1963



NPS and Hydrokinetics

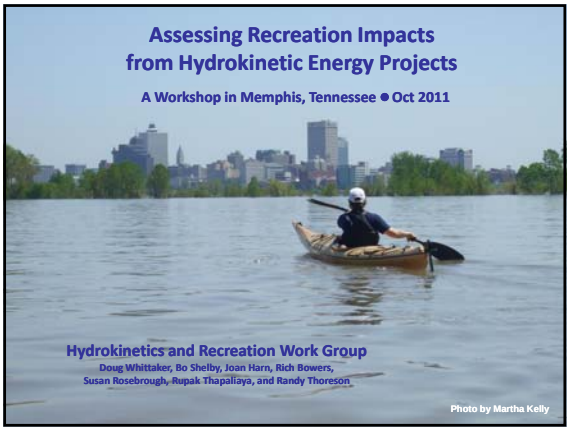
Department of Energy (DOE) – report to Congress (2009) relating to MHK projects
- Covered varying types of impacts and issues
- Did not cover Social and Recreation impacts

Department of Energy (DOE)
- Supported a Study relating to Recreation
- Cooperative effort between DOE, NPS, HRC and OSU Confluence Consulting
- Document produced by Hydro Work Group. Completed in December 2010 . Available in 2011.

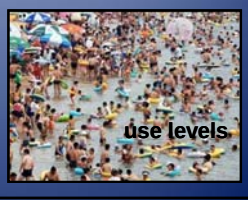


Key elements of the document

- Types of Hydrokinetics Projects
- Types of recreation in Hydrokinetic settings
- Concepts for assessing impacts
- Potential impacts on recreation opportunities
- Types of studies for recreation impacts of Hydrokinetics projects



Recreation management is not just about…



Experiences

The recreation opportunity spectrum

Primitive — Paved

Direct vs. indirect effects
Shorter vs. longer-term effects

Scale and cumulative effects

Other development / uses

Other potential restrictions

A progression of study effort

1. Desk top & secondary sources

2. Limited studies

3. Intensive studies

Protection & mitigation strategies

- More vs. less sensitive areas
- Reducing impacts (project modifications)
- Mitigation (trade-offs)

Types of Large River Recreation: Non-motorized canoeing and kayaking

Elmore Holmes

Photo by Martha Kelly

Motorized "pleasure craft"

Bob Gosford

Boat-based fishing

Shore-based fishing

John Stetz Desoto Camera Club

Beach use (boat and road-accessible)

Tom Haynie

Day and overnight outfitting

Motorized sightseeing craft

Long-distance cruising – non-motorized

Long-distance cruising – motorized

Competitive events

Facilities and infrastructure

Tom Haynie

Shore-based sightseeing

Tom Haynie

Potential Impacts

Types of restrictions

Exclusions (no use)

Restrictions (activity limits)

Reasons for restrictions: Device damage or security

Considerations

US Army Corps of Engineers

Device specifications
Recreation uses and users
Marine or river conditions
Safety mitigation

Safety mitigation

Aids to navigation: markers, education, SAR

Aesthetics

Viewscapes & soundscapes

People value natural sights and sounds

Assessing impacts is challenging

Considerations

Device specifications and location

Construction & maintenance activity

Type of recreation

ROS setting

Tom Haynie

Device specifications and location

Distance from shore/activity centers

Size and shape

Visibility above/under water

Sound volume and duration

Day vs. night

SeaGen tidal current generator, Northern Ireland (flickr.com/snoroma)

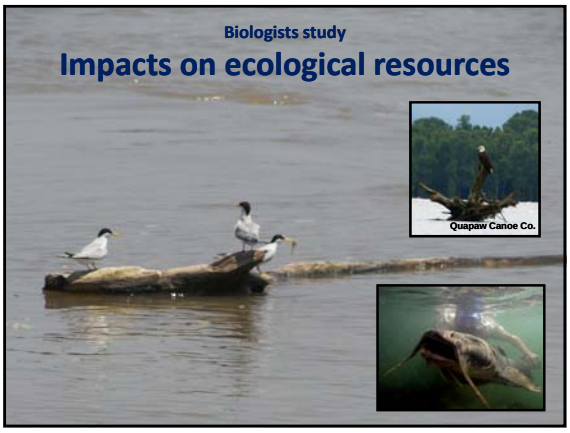
Construction and maintenance

Frequency and duration

Salvage / wreckage?

Logistics of deployment and maintenance

Coast Guard buoy tender –Tom Haynie



Stakeholders !!

- Miss. Wild miles
- Local, Regional, National interest groups
- Clubs. Organizations
- Local citizens
- Shoreline property owners
- Non profits
- Local gov't
- The business community

Main Conclusion:
Recreation (including aesthetics and land use), as it relates to Hydrokinetics impacts, can be recognized and evaluated in a systematic way !

Thank You !

USACE New Orleans District Approach to Evaluating Hydrokinetic Projects

Will Veatch
Hydrologist
Hydraulics and Hydrologic Branch

Brenda Archer
Environmental Resources Specialist
Regulatory Branch

Hydrokinetic Turbines Workshop
29 Feb – 1 Mar 2012
Vicksburg, MS

US Army Corps of Engineers
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MVN Approach to Hydrokinetics

- ***Overview of New Orleans District***
- ***MVN Regulatory Process***
- ***MVN Regulatory Process for Hydrokinetic Turbine Projects***
- ***Areas of Concern***
- ***Conclusions and Discussion***

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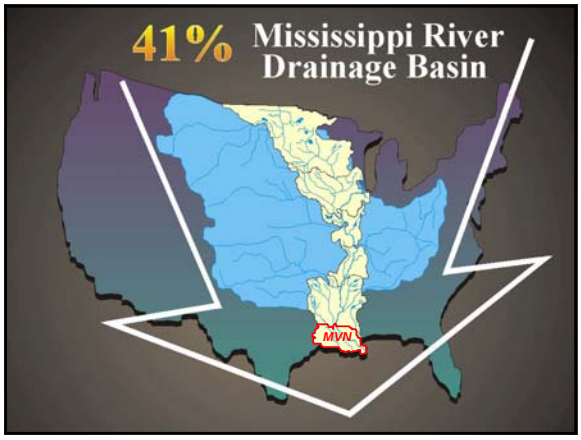

MVN Regulatory Process

- ***DA Permits***
  - Section 10 Rivers and Harbors Act (navigable waters)
  - Section 404 Clean Water Act (waters of the U.S. including wetlands)
- ***Typical Permit Process***
  - Pre-application consultation (optional, informal MVN review team)
  - Permit application submission
  - Review of permit app (incl. Public Interest Review)
  - Permit decision

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MVN Regulatory Permit Process For Hydrokinetic Turbine Projects

- ***Pre-application consultation***
  - FERC is the lead federal agency, requires pre-application consultations
  - MVD requested Regulatory have a formal review team, Hydrokinetic Project Team, multiple disciplines (Hydraulics, Dredging, Channel Stabilization, Counsel, Project Management, Real Estate, Public Affairs)
- ***Permit application submission***
  - U.S. Coast Guard and FERC government process workshop
  - FERC license app and USACE DA app coordinated submittal
- ***Review of Permit App (incl. Public Interest Review)***
  - Review is the same; provide comments and recommendations during the pre-app and the development of an EIS;
- ***Permit Decision***
  - FERC license incl. USACE Section 10 RHA special conditions
  - USACE, if applicable, issues a separate Section 404 permit

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Areas of Concern

Public Interest Review Evaluation

- Water Quality
- Wetlands
- Fish and Wildlife
- Navigation
- Floodplain Management
  - ➢Sedimentation
  - ➢Flowline
  - ➢Channel Stability

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Areas of Concern

- Water Quality
  - ➢Evaluate compliance with applicable effluent limitations and water quality standards
  - ➢Major concern is the leakage of lubricants, etc.
- Wetlands
  - ➢Evaluate impacts to wetlands in the project area
  - ➢Major concern are impacts to riparian wetlands associated
- Fish and Wildlife
  - ➢Evaluate impacts to fish and wildlife (incl. T&E) within the entire project area

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Areas of Concern: Navigation

- Low-water navigational hazards

- Altered river currents
- Traffic during installation / maintenance
- Altered sedimentation patterns → hazards and currents

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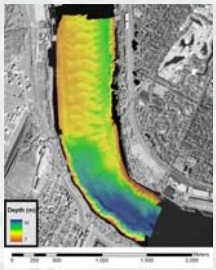
Areas of Concern: Sedimentation

- Altered water surface profile
- Sediment availability for coastal projects
- Effects on shipping channel
- Dredge access
- Local and cumulative effects



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Areas of Concern: Flowline

- Increased channel roughness
- Altered bedforms
- Batture construction

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Areas of Concern: Channel Stability

- Revetment integrity

- Access to failure areas
- Altered currents
- Levee loading during construction
- Power lines crossing levees

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Conclusions and Discussion

• MVN supports alternative energy and further development of hydrokinetic electricity, provided concerns are addressed.

•We work closely with FERC to streamline our work processes.

•Many concerns remain to be addressed.

•MVN's Hydrokinetic Project Team and Independent Technical Review Team address concerns and technical validity.

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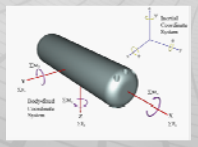
Assessment of Fish Behavior and Vulnerability to Hydrokinetic Devices

Contact - Mark Weiland



1

Ecological Indicators of Hydrokinetic "stress"

- Stress includes:
  - Trauma
  - Altered behavior or performance
  - Changes in migration patterns or timings
  - Larval dispersal and settlement
- Survival
  - Immediate and Delayed mortality
- Long-term effects
  - Reproductive potential
  - Population structure
  - Community interactions

2

Acoustic Monitoring

- Record and monitor underwater sound from wide array of sources
  - Pressure
  - Vibrations
  - Explosions
  - Seismic exploration
- Characterize environment
- Monitor animal behavior
  - Individuals
  - Run at large
  - Over distances in many water conditions
  - Not depth dependent

3

Acoustic Systems

- Juvenile Salmon Acoustic Telemetry System (JSATS)
  - Cabled Arrays
  - Autonomous Nodes
  - Mobile Tracking
- Hydroacoustics
  - Fixed
  - Mobile
- Acoustic Camera
  - DIDSON
  - BlueView
- Marine Mammal Monitoring system
  - Active
  - Passive
- Other Passive Monitoring Systems

4

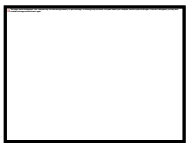
JSATS-Tagging Alternatives

Transmitter / tag treatment	Picture	Weight in Water (g)	Weight in Air (g)	Volume (mL)
PIT		0.059	0.096	0.036
Single battery		0.191	0.305	0.114
Single battery w/ PIT		0.250	0.400	0.150
Double battery w/ PIT		0.356	0.536	0.180

5

JSATS – Injectable Acoustic Micro-transmitter

- In development
  - Spring 2013 in-water trial
- Weight in air 0.2 g
- Weight in water ~0.135 g
- Volume 100 mm^3
  - ~14 mm long x 3.2 mm diameter
- Source level 156dB re:1µPa at 1m
- Code set millions of possible codes



6

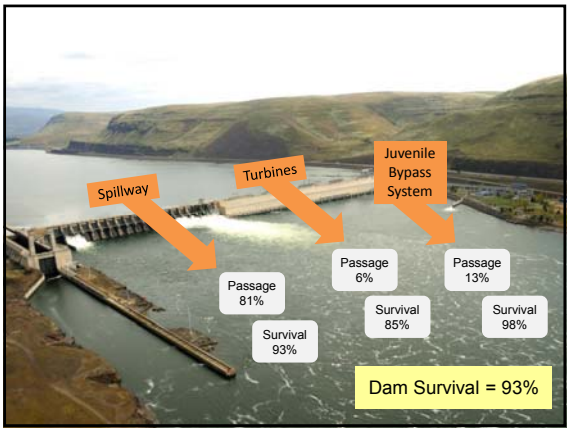
JSATS is not *just* about the technology…

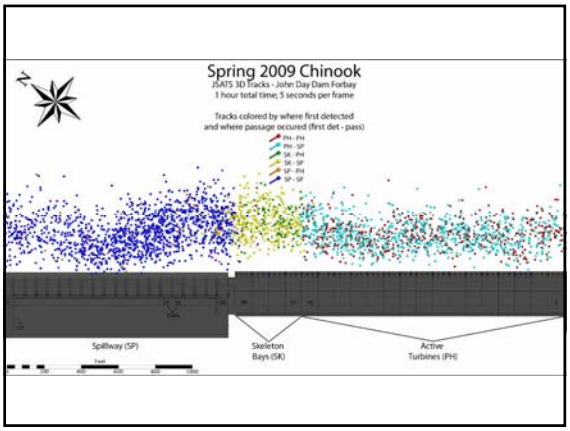
- Bio-compatibility
  - Tag Adhesions
  - Tissue Reactions to Tags
  - Tag Expulsion
  - Tag Burden
  - Suture Location
  - Various Suture Materials
  - Reducing # of Sutures
  - Reducing Suture Profile
  - Degradation MS-222
  - Time in MS-222
  - Buffering MS-222
  - Improving Surgeon Training
- Condition of fish

7

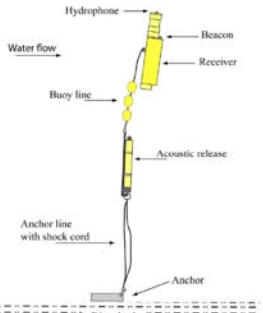
JSATS – Cabled Array

8





JSATS - Autonomous Receivers



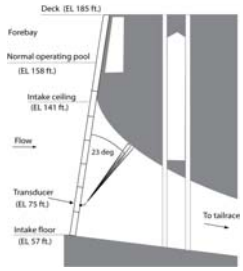
- On-board power and data storage
- Measures and stores environmental data (temp, depth, tilt)
- Detection range in freshwater (~300 m)

JSATS – Autonomous Receivers

12

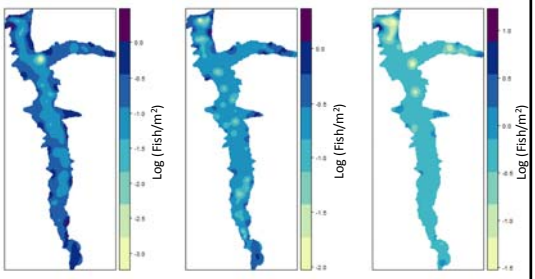
Hydroacoustics

Fixed **Mobile**



13

Fish Density (size class)



35mm-75mm 75mm – 225mm >225mm

Size determination based on target strength

Acoustic Cameras

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Passive Monitoring Systems

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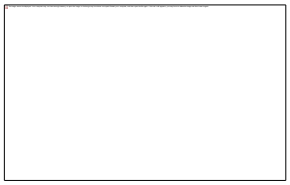
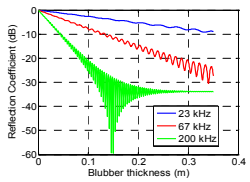
Acoustic Monitoring System for Marine Mammals – Active and Passive





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Sensor Fish Device

- The Sensor Fish measures:
  - 3 components of linear acceleration (x, y, z),
  - 3 components of angular velocity (pitch, roll, yaw)
  - temperature
  - absolute pressure
- Unit is user-programmable, with a data collection time up to 233 s, and a sampling frequency of 2000 Hz
- Reusable with a wireless downloading capability

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Construction:

Completed:

(photos courtesy of USACE)

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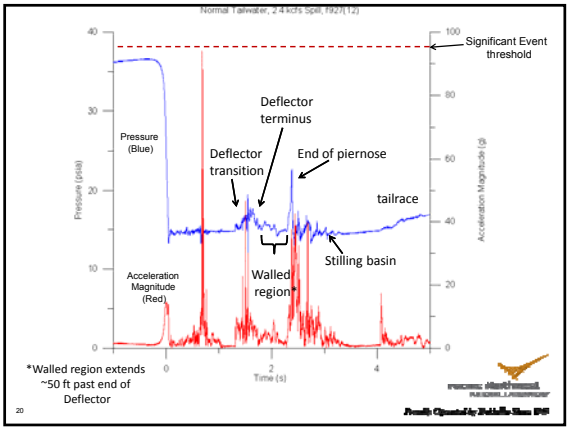

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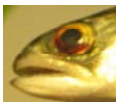
Hydrokinetic Exposure-Response Management Criteria



- Needed for risk assessment(s)
- Move past mortality/moribund estimates
  - Severe measure used for survivorship
  - Poor indicator of physiological or behavioral alterations
  - Not relative to performance impairments or delayed mortality
- ***Resolution***:
  - Metric sensitive to thresholds of injury
  - Metric sensitive to physiological impairments
  - Considerate of mortality and moribund
  - Inclusive of implosive sound levels

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Fish Index of Trauma (FIT)

$$FRSWI = \sum Severity * Injury$$

Fish Response Severity Weighted Index

Severity of the actual injury measure:
Slight = 1
Significant= 2
Severe = 3

FIT Injury Measures:
Not present = 0
Mild = 1
Moderate = 3
Mortal = 5

Observation	Hemorrhage: Eye
Severity	Significant: 2
Injury	Moderate: 3
Severity*Injury	6
Repetitive	…
Count of injuries	3
∑ (Severity*Injury)	18

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Summary

- There are multiple acoustic systems available for evaluating the "stress" of hydrokinetic turbines on fish and fish communities.
- Additional monitoring tools to measure what the fish are experiencing.
- Recommend baseline monitoring prior to installation of hydrokinetic turbines to provide a reference level to assess against.
- There are compromises with the technologies and need to identify what technology is best for what application